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# STUDY OF SLEEPING IN A CHEMICAL PROTECTIVE ENSEMBLE IN A WARFARE ENVIRONMENT


BY
GIAN M. CACIOPPO
JAMES F. ANNIS

MAC AULAY-BROWN, INC.
3989 COLONEL GLENN HIGHWAY
FAIRBORN, OHIO 45324

WEBB ASSOCIATES
YELLOW SPRINGS, OHIO


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Experiments were performed to evaluate the quality of sleep experienced by individuals wearing different chemical protective ensembles (CPE). A series of seven experiments were conducted in which two test subjects slept overnight in an environmentally controlled room while wearing either pajamas (control ensemble) or one of three different CPEs. The three CPEs tested were: the standard West German ground crew ensemble, an ensemble comprised of a combination of equipment of which the Canadian chemical protective coverall was
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the principal item of clothing, and the U.S. Army standard ground crew ensemble. Body temperatures, sleep records, and other physiological measurements were monitored overnight and form the basis of the objective evaluation. Subjective data were collected by an experiment monitor who kept the test participants under constant observation. Additionally, the participants were required to complete a standard debriefing questionnaire form each post-experiment morning. Because of the limited scope of the experiment, statistical analysis was not appropriate. However, both the objective and subjective data reflected consistent trends and allow confidence in the assessment that current U.S. and NATO CPE combinations provide for adequate sleep quality.

## SUMMARY

Two subjects were fully instrumented and monitored for sleep quality while wearing various Chemical Protective Ensemble (CPE) combinations through the night. Evaluations were conducted in an environmental chamber, tightly controlled for constant temperature and humidity. The CPE conditions consisted of baseline (pajamas), standard U.S. Army ground crew ensemble, standard West German ground crew ensemble, and a combination ensemble based on the Canadian coverall. For all conditions, subjects experienced surprisingly high sleep quality. Even with limited replications, it is readily apparent that subjects' restfulness and ability to perform work the following day compare favorably to baseline. There were no obvious differences in quantitative comparisons of ensembles, however, subjects had a strong subjective preference for the West German CPE.

Because of the limited scope of the experiment, statistical analysis was not appropriate. However, both the objective and subjective data reflect consistent trends and allow confidence in the assessment that current U.S. and NATO CPE combinations provide for adequate sleep quality.

# PREFACE

This study was initiated by the Individual Protection Laboratory, U.S. Army Natick Research and Development Laboratories, Natick, Massachusetts 01760. The research was conducted between August 26, 1981, and December 2, 1982, under Army Contract DAAK60-81-R-0105 by MacAulay-Brown, Inc., 3989 Colonel Glenn Highway, Fairborn, Ohio 45324. Assistance was provided under subcontract by Webb Associates, P.O. Box 308, Yellow Springs, Ohio 45387. The work was performed in support of "Analytical Study of a Sleeping Soldier in a Chemical Warfare Environment," Project No. 1L162723AH98CD058.

The authors would like to acknowledge the assistance and the technical support provided by Mr. Kenneth Moy, Project Officer, of the Individual Protection Laboratory, Natick Research and Development Laboratories.

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# STUDY OF SLEEPING IN A CHEMICAL PROTECTIVE ENSEMBLE IN A WARFARE ENVIRONMENT

## INTRODUCTION

By its very nature chemical protective clothing tends to be bulky, restrictive to motion, and a thermal and respiratory burden to the wearer under most conditions. Assuming the individual items that make up a given chemical protective ensemble (CPE) represent the best that technology can offer, and that with proper usage the ensemble could effectively protect soldiers against the majority of agents that are known to be available for potential combat usage, failures will be those associated with equipment breakdown, individual misuse, and accidentally induced loss (or reduction) of protective capability. If a soldier is well trained and properly outfitted, most failures will be accidentally induced. The highest incidence rate of accidental failures is likely to be associated with periods of sleep when the individual soldier is unaware of impending difficulties. While unconscious, dishevelment of clothing and respirators with resultant loss of seal may go undetected. The ability of soldiers to sleep quietly while wearing the CPE may be directly related to the overall comfort associated with a given ensemble.

This report describes the results obtained in a series of seven experiments in which two test subjects slept overnight in an environmentally controlled room while wearing either pajamas (control ensemble #P) or one of three different CPEs. The three CPEs tested were: the standard West German ground crew ensemble (ensemble A); an ensemble that comprised a combination of equipment of which the Canadian chemical protective coverall was the principal item of clothing (ensemble B); and the U.S. Army standard ground crew ensemble (ensemble C). Body temperatures, sleep

records, and other physiological measurements were monitored overnight and form the basis of the objective evaluation of sleep quality possible with the various ensembles. Functional and subjective aspects are also examined.

## Background

Seven overnight experiments were completed over a 15-day period. Two subjects were tested simultaneously while wearing one of four different clothing ensembles during the experimental series. Following two control nights in which the subjects slept in pajamas, the three different chemical protective ensembles were tested. The order of use of the CPEs varied for the two subjects, and experiments were repeated for two of the ensembles. The order of the experiments and ensembles tested is given in Table 1. On nights between experiments the subjects slept at home, and both men continued their normal daily routines throughout the series. All experiments were conducted in a darkened, environmentally controlled room that maintained a dry bulb temperature ($T_{db}$) of 25° ∓ 0.5°C and vapor pressure of 14 ∓1 mm Hg (55%-65% relative humidity). Each experiment required nearly 10 hours to complete. The timing of the various activities for a complete experiment is outlined in Table 2. The proposed (and typical for sleep studies) eight hours of sleep time was shortened for our subjects, in order to agree more closely with their normal sleep habits. During the 6 hours and 45 minutes (405 minutes) of time in bed, both environmental and physiological measurements were continuously recorded while the subjects were under constant observation by the experiment monitor. Four times each night, 20-second periods of white noise of several different intensities were superimposed on the normal background noise. The presentation time and the intensities of the noise were fixed and constant for all experiments. This noise simulated random combat noises and was referred to as the "combat scenario." Each post-experiment morning, subjects were required to complete a standard debriefing questionnaire form (see Appendix A).

Table 1. EXPERIMENTAL PARADIGM

| | MONDAY | TUESDAY | WEDNESDAY | THURSDAY | FRIDAY | SATURDAY |
|---|---|---|---|---|---|---|
| Week 1 | | | expt #1 | | expt #2 | |
| Subj. 1 | | | P-control(1) | | P-control(2) | |
| Subj. 2 | | | P-control(2) | | P-control(1) | |
| Week 2 | | expt #3 | | expt #4 | | expt #5 |
| Subj. 1 | | ensemble A | | ensemble B | | ensemble C |
| Subj. 2 | | ensemble C | | ensemble A | | ensemble B |
| Week 3 | expt #6 | | expt #7 | | | |
| Subj. 1 | ensemble C | | ensemble A | | | |
| Subj. 2 | ensemble A | | ensemble C | | | |

P-control (1): subject in pajamas, full instrumentation

P-control (2): subject in pajamas, partial instrumentation

ensemble A: West German

ensemble B: Canadian combination

ensemble C: U.S. Army

Table 2. TIMING OF EXPERIMENTAL ACTIVITIES

| TIME | | ACTIVITY |
|---|---|---|
| 2100 | ------ | Subjects report to laboratory |
| 2100-2200 | ---- | Instrumentation with electrodes, thermistors, etc. |
| 2200-2245 | ---- | Nude weight; dressing |
| 2245 | ------ | Clothed weight; subjects enter chamber |
| 2245-2300 | ---- | Connect and check out instrumentation |
| 2300 | ------ | Lights out; monitoring begins; experiment time = 0 |
| 2300-0545 | ---- | Sleep period; monitoring continues |
| 0545 | ------ | Subjects awakened |
| 0545-0630 | ---- | Weigh out; undressing; completion of questionnaire |

## Ensembles

The following description of the test ensembles is nontechnical and intended to outline briefly the general characteristics of each ensemble. For convenience, the clothing worn during the initial control experiment is also listed as a test ensemble (P-control). During each experiment, the subjects slept on air mattresses (military issue) and pillows were available for optional use depending upon the preference of the subject. For control experiments only, blankets (military, wool, OD) were also used if desired. The U.S. ensemble (C) and the West German ensemble (A) were complete ground crew ensembles; however, ensemble B comprised an international mix of items. The basic garment was the Canadian coverall (unipiece); the remaining items are listed below.

Control - Ensemble P

This garment assembly consisted of light cotton-polyester pajama bottoms, which were worn with cotton T-shirts. Lightweight stockings completed the ensemble. This clothing was supplied by the subjects. The same pieces were also used as undergarments with all the CPE assemblies.

West German - Ensemble A

The West German ensemble consisted of a jacket, trousers, boots, gloves, and respirator. Two complete assemblies had been supplied. Sizes GR.10 and GR.11 were supplied for the jackets, trousers, and gloves; the respirators were both size 2; the size of the two pairs of boots could not be identified. Weight of the total ensembles was 3.8

and 4.0 kg for the smaller and larger sizes, respectively. The jacket was blouse style with an attached hood. Drawstring closures were used at the face, waist, and hip locations, and Velcro closures were used at the wrist. The trousers had a wide, pleated top with Velcro take-ups at the waist and ankles. The rubber boots were pull-on type with a drawstring near the top. The rubber gloves had a flocked lining and were worn without inserts. The full-face respirator possessed a reflected type face seal, nose cup, 5-point rubber strap suspension, and a midline positioned voicemitter device and screw-in filter canister. Boots and gloves were tucked under the ends of the sleeves and trousers. Size combinations were used that furnished the best fit for the subjects.

Canadian Combination - Ensemble B

This ensemble, which weighed 3.8 kg, consisted of the Canadian chemical protective coverall (two assemblies supplied, sized medium regular) the U.S. M17A1 respirator; and West German boots and gloves. The coverall, single piece with attached hood, was equiped with a full length, front midline zipper augmented by Velcro tape. Velcro closures were used at the wrists and ankles. The head seal used a combination of elastic and a Velcro strap for size adjustment on one side. Other items used in this combination are described elsewhere. The original plan was to use the Canadian coverall with only U.S. Army accessory items; however, one subject selected the West German boots and gloves despite instructions to use the U.S. items. The monitor did not discover what the subject was wearing until after the experiment had begun. The U.S. M17A1 respirator, without the M6A2 hood was

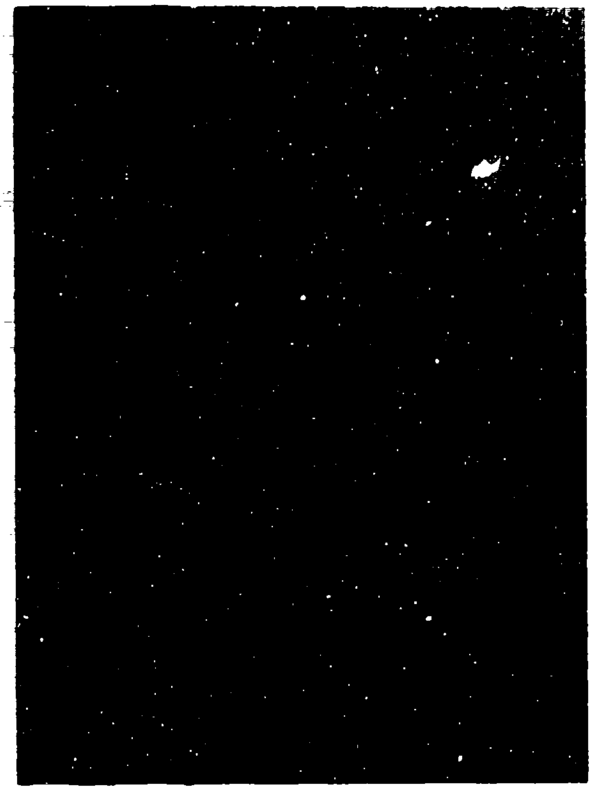
being worn, as directed. For continuity, the same combination was used during the next experiment with the other subject.

U.S. Army - Ensemble C

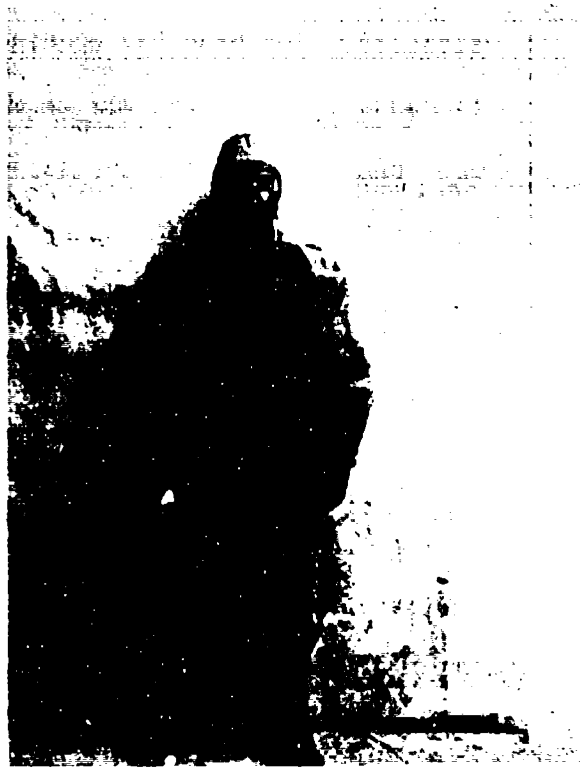
The basic items were jacket and trousers (NSN: 8415-00-177-5007), gloves plus inserts (NSN: 8415-01-033-3517), foot covers (NSN: 8430-01-021-5978), M17 and M17A1 respirators (NSN: 4240-00-926-4201), and M6A2 hood. Two complete ensembles were supplied, one medium and one large for the jacket, trousers, and gloves; one medium M17A1 with drinking tube and resuscitation apparatus, and one medium M17; two hoods and two pairs of foot covers, not sized. The jacket had a full length entry zipper supplemented with metal snaps, elastic closures at the wrists, and elastic plus a drawstring to pull it tight over the lower torso. The trousers had a zippered fly and zippers on the outside of the lower leg for ease of donning. The leg zippers were supplemented by Velcro strips and a drawstring at the bottom. Size adjustment at the waist was made by lateral straps. Belt loops were present but no belts were used. Three metal snaps in the rear of the jacket and trousers acted to prevent gapping during torso flexion. The black butyl rubber gloves were worn with light cotton inserts. The rubber foot covers were unisized and used shoestring lacings, which extend from eyelets on the edge of the sole and over the top of the foot, in order to draw the cover tight upon the foot and lower leg. The M17 and M17A1 respirators had bilateral filter pads and front midline-positioned voicemitters and exhalation ports. The protective hood (M6A2) worn with the M17 respirator was made of rubberized fabric and covered the entire head and shoulder area of the

subjects. The hood had openings which were sized and positioned to fit snugly around the M17 or M17A1 ports and lenses. The hood was equipped with a mid-front zipper for donning and a drawstring to constrict it at the neck region. The shoulder apron was secured by adjustable straps which pass under the axilla and attach to the front of the apron with Velcro patches. The weight of the complete ensemble C was 4.3 to 4.4 kg depending upon the size combination used. The subjects made their own selection of size combinations to produce the best possible fit.

Photographs of the subjects in some of the ensembles are presented in the following pages.

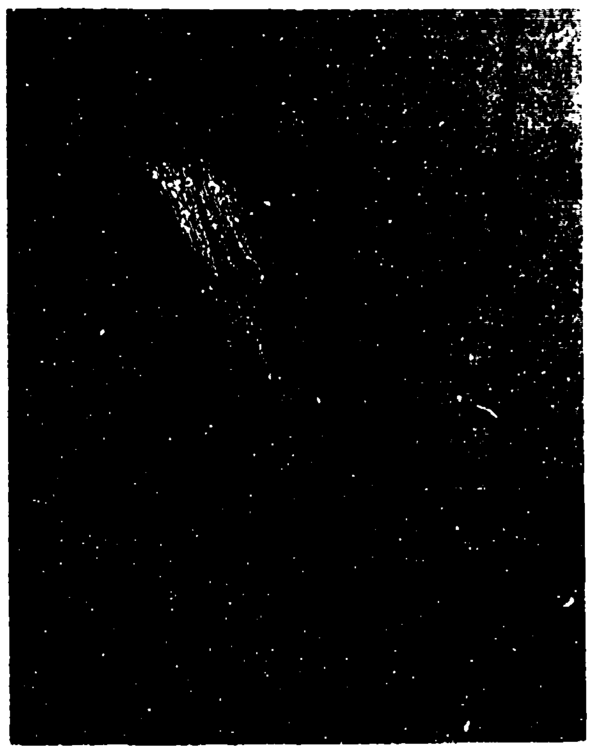


Subject 1: Control (P)



Subject 1: West German (A)

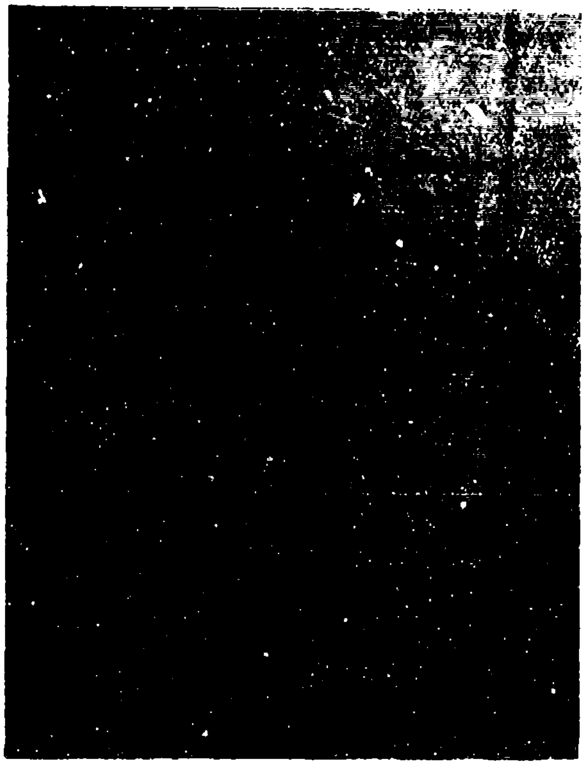
Subject 1: U.S. Army (C)



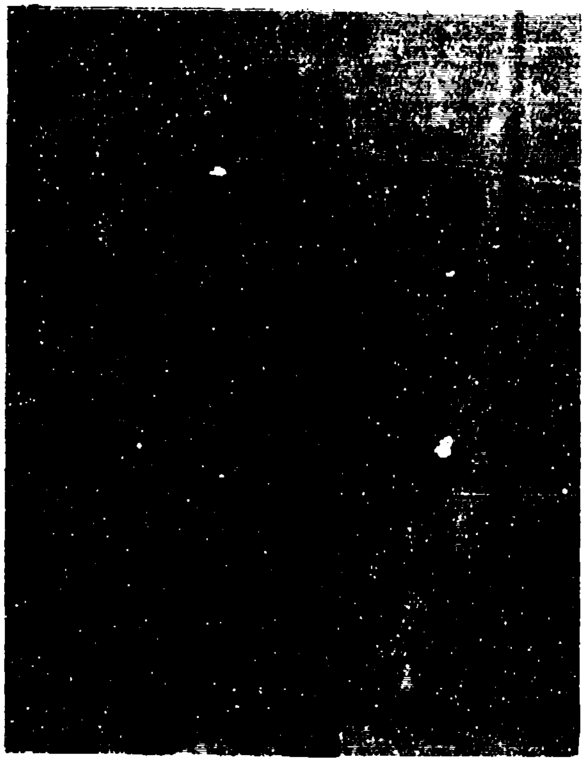
Subject 1: U.S. Army (C)

Subject 2: U.S. Army (C)

Subject 2: U.S. Army (C)



Subject 2: West German (A)



Subject 2: West German (A)

# METHOD

## Subjects

Prior to subject participation, both men were required to complete a series of screening procedures designed to determine their state of health, define their level of fitness, and describe their physical characteristics. The tests and procedures completed were the following:

1. History and physical examination by a physician
2. Blood tests, including hemogram and more than 20 assorted biochemistry tests
3. Resting electrocardiogram (ECG), standard 12-lead
4. Exercise ECG, single lead
5. Fitness level assessment by submaximal bicycle ergometry
6. Body density determination by underwater weight, including lung residual volume
7. Anthropometry, including skinfold thickness measurements and a variety of body lengths, girths, and diameters.

Descriptive data for both subjects are presented in Table 3.

Subject 1 is employed by the U.S. Postal Service, and as a mail carrier normally walks about 36 km/day. During the experiments his work assignment was in the office. Because he currently serves as the chemical warfare training officer for a number of Ohio Army National Guard units, he is trained and experienced in the application and use of chemical warfare equipment and agents. Because of his level of expertise and his interest in chemical protective clothing, Subject 1 was highly motivated.

Table 3. TEST SUBJECT DESCRIPTIVE DATA

| Measurement: | Subject #1 | Subject #2 |
|---|---|---|
| Age | 31 yrs | 38 yrs |
| Height | 166.7 cm | 180.6 cm |
| Weight: begin | 79.85 kg | 83.75 kg |
| end | 79.66 kg | 83.27 kg |
| [1]Fitness, $VO_2$ max, est. | 2.43 L/min | 2.30 L/min |
| [2]Density | 1.030 gm/mL | 1.043 gm/mL |
| [3]Body fat | 30.6% | 24.6% |
| [4]Skinfold thickness | 20.0 mm | 15.8 mm |
| Chest circumference | 103.4 cm | 100.4 cm |
| Waist circumference | 100.2 cm | 93.9 cm |
| Hip circumference | 101.8 cm | 99.2 cm |
| Thigh circumference | 49.2 cm | 51.1 cm |
| Calf circumference | 46.2 cm | 36.8 cm |
| Bicep circumference (relaxed) | 30.9 cm | 31.1 cm |
| Leg length | 78.8 cm | 85.0 cm |
| Arm length | 64.1 cm | 64.3 cm |
| Trunk length | 58.8 cm | 63.7 cm |

1 Estimated by submaximal bicycle ergometry (Astrand, 1960).

2 From underwater weight corrected for lung residual volume.

3 Predicted from body density (Siri, 1961).

4 Measured with Lange skinfold caliper; values are means of triceps, subscapular, juxtaumbilicus, and calf.

Subject 2 works as a dispatcher for a materials handling firm. He too is currently active in the National Guard and is experienced and trained in the use of U.S. Army chemical protective equipment. This man was also highly motivated, and both men made excellent test subjects. Their level of interest added significantly to the study, and their subjective evaluations and observations must be viewed as having more value than would have been the case if they had not had previous experience and training.

During the screening period, the test routines were described to the subjects, and they were made familiar with the facilities at the laboratory. Other procedures consistent with good human use practice were followed. The protocol and procedures employed did not significantly vary from those approved by the Webb Associates Institutional Review Board under Special Assurance techniques. Signed consent forms were completed by each man.

## Procedures

### Environmental measurements

All experiments were performed in the Webb Associates' environmentally controlled chamber under fixed and stable thermal conditions. Except for brief control transients, the chamber conditions throughout the test series were: $25° \mp 0.5°C$ dry bulb temperature ($T_{db}$) and $20° \mp 1.5°C$ wet bulb temperature ($T_{wb}$). The resultant vapor pressure averaged 15 mm Hg, which is equivalent to a relative humidity of approximately 65%. Air flow, although not measured for this study, is known to run $40 \mp 10$ feet/minute from ceiling to floor. The chamber was dark for the entire sleep period. The only light was incidental background light passing through an obser-

vation window located about three feet above the supine subjects. They were positioned with about four feet of space between them. All temperatures were sensed via thermistors (YSI 400 series) which are regularly checked for absolute accuracy (∓ 0.2°C).

<u>Physiological measurements</u>

a. Body temperatures

Rectal temperature ($T_{re}$) and skin temperatures ($T_{sk}$) of both subjects were monitored throughout each experiment. $T_{re}$ was sensed by a thermistor (YSI 401) positioned at a depth of 12 cm in the subject's rectum. Four disk thermistors (YSI 425) were used to measure $T_{sk}$. Based on a large number of laboratory experiments, the following four sites were used to give the most reliable indication of mean skin temperature: biceps, abdomen, kidney, and calf. The skin thermistors were held in place by electrode-type adhesive disks which left the external surface of each probe uncovered, hence uninsulated from environmental influence.

b. Sweat rates

In order to augment body temperature data, and as an index of thermal burden or discomfort, sweat rates were determined using the method of weight change. Subjects were weighed on a clinical platform scale (accurate to ∓ 50 gm) before and after each experiment. To enable division of the total body water loss into that which evaporated and that which was retained in the garments, subjects were weighed first in their undergarments and then in their full assemblies, and the process was reversed at the end of the experiment. Some error was introduced due to the time required

for dressing and undressing, about 35 minutes. Post-experiment weights of the subjects dressed only in the undergarments were not obtained after experiment 7 due to the excitement surrounding completion of the final night.

c. Sleep records

Sleep records consisting of electroencephalographs (EEG, single channel) and electromyographs (EMG, single channel) were obtained overnight for each subject during the experiments in which CPEs were worn. In addition, during control experiments (1 and 2), both subjects were instrumented to obtain electrooculographic recordings (EOG, 2 channel). The EOG permits scoring of rapid eye movement sleep (REM, stage R), which is associated with periods of dreaming. The quality of the EEG and EOG recordings obtained on Subject 1 in experiment 1 were judged unsatisfactory for scoring; hence no baseline, first night data of this type were available for comparative purposes. The EMG from this experiment was, however, used for determining sleep latency and periods of wakefulness and/or movement.

In order to obtain sleep records, a number of electrodes must be applied to the head and neck area of the subject. Standard positions were used with one small exception, that of the EMG electrodes that were positioned on the upper neck instead of on the chin. The positions are outlined below:

EEG: One electrode was located midlaterally on the bitragion-coronal arc line. The subject's right side location was used, a position usually labelled C4 in electroen-

cephalography. This electrode is referenced to a second one positioned over the mastoid. Either the right side (A2) or the left side (A1) reference site was used. Subjects were routinely instrumented with both A1 and A2 electrodes.

EOG: Electrodes were positioned 1 cm lateral to each eye. One was 1 cm above (right) and the other 1 cm below (left) the mid-eye level line. Both of these electrodes were referenced to either the A1 or the A2 electrodes.

EMG: Two electrodes were positioned on both sides of the anterior neck approximately midway in the depression created between the sternocleidomastoid muscle and the lateral aspect of the thyroid cartilage. This position worked well for these experiments. It not only cleared the mental-submental area for the respirators used but also enabled the detection of good electrocardiographic signals simultaneously (see d., Related measurements and procedures, below).

The EEG and EOG were detected by small electrodes (IVM, Inc.) measuring 0.5 cm in diameter. The electrodes used for the EMG (also for the ECG and heart rate) were larger (1 cm in diameter). All electrodes were of the silver/silver-chloride type. Preparation and installation of the electrodes required approximately 40 minutes per subject each night. The preparation procedure included shaving (where necessary), abrasion of the skin with a plastic scrub pad, followed by an acetone wash to remove body oils. Electrodes containing electrolytic gel were applied to the cleaned sites using adhesive disks. The electrodes were then

covered with a layer of hypoallergenic surgical tape. Electrode-pair resistance was checked using an ohmmeter developed for sleep studies. In order to assure satisfactory tracing quality, the interelectrode resistance had to be less than 5,000 ohms. All sleep records were obtained using a 4-channel polygraph (Grass Instruments, model 79).

The sleep records were scored in stages using the guidelines proposed by the Association for the Psychophysiological Study of Sleep (Rechtschaffen and Kales, 1968). Because there were no EOG tracings during the suited experiments, only sleep stages 2, 3, and 4 were scored on the basis of the presence of characteristic patterns, e.g. K complexes and sleep spindles for stage 2, and the percentage of high amplitude-slow wave sleep (delta sleep) in a given 30-second epoch. In the absence of EOG tracings, REM sleep could not be scored. Periods of high tonic EMG activity lasting at least 30 seconds (1 epoch), or that combined with alpha activity, qualified for periods of wakefulness.

d. Related measurements and procedures

Heart rates of the subjects were monitored throughout each experiment. During the control experiments (1 and 2), heart rates and/or ECG patterns were obtained using a radio-telemetry system (Biocom). Signals were processed by a modified FM receiver and were available for either audio, cardiotachometric, or oscillographic display (ECG) for monitoring purposes. As mentioned above, heart rates could be counted from the R spikes superimposed on the EMG recordings. During many of the experi-

ments, and particularly during quiet periods of sleep, the EMG tracing became almost pure, clean ECG signals. The quality and reliability of this source of heart monitoring were such that the telemetry was not used during CPE-suited experiments.

Seal integrity of the respirators was monitored overnight by sampling the $CO_2$ level inside the oronasal area of each mask. A small sample of mixed room and expired air (100 mL/min) was pumped through a sensitive infrared $CO_2$ analyzer (Beckman Instruments, model 864). The output of the analyzer was displayed on a digital voltmeter, as well as electronically totalled (averaged on a 5-min time basis), by the data processing system. The system was used on a time-sharing basis for the two subjects. This procedure was included as a safety measure anticipating that respirator seal leakage could effectively increase the dead space rebreathing, causing the $CO_2$ level to increase. It was also hoped that mask seal violations could be used for casualty prediction. In order to sample from the oronasal area of three of the masks, it was necessary to penetrate the mask wall with a small sample tube (1.6 mm ID Tygon). Samples were drawn via the drinking system of the M17A1 respirator. It was learned during the experiments that the position of the sample port within the oronasal cup is critical if other than breath-by-breath expired $CO_2$ levels are to be obtained.

Combat scenario

During all experiments, an auditory alarm over a range of 86 to 105 dB was presented four times each night. The alarm was included as a simula-

tion of combat noise. The duration of each alarm was 20 seconds. Because of the impact that the alarms might have on the subjects at various times of the night, during different stages of sleep, the schedule for the times of presentation and dB levels was the same for all experiments. This schedule is given in Table 4. A tape-recorded soundtrack normally used for vigilance testing (Wilkinson, 1974) was amplified and presented within the test chamber via a **horn-type** speaker located approximately 1.5 meters above the heads of the supine subjects. The tape consisted of white noise upon which were superimposed short bursts of fixed frequency tones which reoccurred at 2-second intervals. The amplifier gain settings were calibrated using a sound intensity meter (Realistic). The variation in intensity over the chamber floor area, regardless of location, was not more than 1 dB. The precise time of presentation of alarms was recorded in the monitor's log and marked on the running polygraph record for later correlation with the magnitude of sleep disruption at the extant sleep stage. (A constant background noise level of 68 dB was associated with the operation of the chamber systems.)

Table 4. COMBAT SCENARIO SCHEDULE

| Time of night (EDST) | Experiment elapsed time (min) | Noise level (dB) |
|---|---|---|
| 2345-0015 | 60 ± 15 | 96 |
| 0015-0145 | 150 ± 15 | 105 |
| 0315-0345 | 270 ± 15 | 86 |
| 0445-0515 | 360 ± 15 | 92 |

Subjective data

In addition to the monitor's log, a formal debriefing questionnaire was completed by each subject, each morning following an experiment. A great number of verbal comments surrounded each experiment, but only those judged to be pertinent were recorded.

Data processing

All temperatures and the $CO_2$ analog signal were processed on-line via a computerized data control system (Hewlett Packard, model 9825 desktop computer; 6940B multiprogrammer; 3456A digital voltmeter). The experiment clock, as well as the polygraph recorder, were sequenced to the data system time base. Temperatures were recorded each minute, averaged, and printed out every five minutes. The analog voltage ($CO_2$) was examined each second, totalized, and the average value printed out every five minutes. Other than a preliminary evaluation, determination of heart rates and final scoring of sleep records were performed after the experiment series was completed.

## RESULTS

Throughout the description of the results, reference will be made to an incident of nausea and vomiting involving Subject 1 during experiment 5. Although this unfortunate incident was not the only difficulty which affected the results of the test series, it was the only one that involved subject safety and significant loss of data. Approximately one hour after lights out, the monitor detected obvious restlessness of Subject 1. High tonic EMG with frank movement, as well as a slightly elevated heart rate (about 15 beats/min above normal for Subject 1) extending well beyond the usual sleep latency period, prompted the monitor to enter the test chamber to investigate the subject's status. The subject reported that he felt "a bit sick at the stomach" and suspected the respirator (M17) was contaminated. At the monitor's insistence, the M17 was removed at that time, washed with clean water, and dried. Because this subject was highly motivated, he proposed to try wearing the M17 again in order to determine whether the apparent sickness was "real or imagined."

At approximately 0100 hours the subject felt better, donned the M17, and tried to go to sleep. Over the next hour and a half (until 0240) the subject intermittently reclined with the respirator and hood in position or rested leaning against the chamber wall without the mask. Monitoring of physiological measurements continued, and it became clear that the subject's status was not improving. In order to minimize disruption of sleep for Subject 2, the monitor suggested that Subject 1 leave the chamber and rest in the laboratory. At 0250 hours the subject entered a nearby bathroom and vomited. For nearly 40 minutes following the vomiting, the

subject sat in the laboratory with the CPE jacket removed, trying to recover. During this period, the suspect M17 was again examined. In order to alleviate the itching and burning that the subject was experiencing in the oronasal area of his face, the monitor applied a layer of anesthetic ointment (Nupercaine) to the area, with a warning to avoid getting the ointment into his eyes. At 0315, without the M17 but otherwise fully suited, the subject reentered the chamber and his instrumentational leads were reconnected. Approximately 15 minutes later, the subject was sleeping soundly and continued to rest well during the remainder of the night, as evidenced by the sleep record. In the morning the subject reported feeling okay, but some stomach discomfort and tightness in the chest continued. By the next evening, when experiment 6 was to begin, the subject said that he was well; however, he had eaten little during the interim period. At the conclusion of experiment 7, the subject was examined by the staff physician, and no evidence of sequelae was found.

**Thermal burden**

Examination and analysis of the $\bar{T}_{sk}$ and $T_{re}$ data disclosed little evidence of thermal burden associated with wearing the CPEs under the conditions of these tests. The total sweat loss, which includes water retained in the garments, or nonevaporative loss, did increase above control rates. The increase averaged 51.5% and 23.0% for Subjects 1 and 2 respectively. These water losses were well within tolerable limits.

A digital presentation of some $\bar{T}_{sk}$ and $T_{re}$ values, as well as the net evaporative loss rates for all experiments, is given in Table 5. The

Table 5. SUMMARY OF SUBJECT BIOTHERMAL RESPONSE

| Expt.# | Clothing ensemble | Rectal temp, $T_{re}$, °C begin | end | high | low | Mean skin temp, $\bar{T}_{sk}$, °C begin | end | high | low | Evap. $H_2O$ loss rate, gm/hr |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Subject #1 | | | | | | | | |
| 1 | P | 36.9 | 36.4 | 36.9 | 36.4 | 33.0 | 33.8 | 35.2 | 33.2 | 42.3 |
| 2 | P | 37.2 | 36.7 | 37.2 | 36.6 | 33.9 | 34.7 | 35.0 | 33.9 | 63.0 |
| 3 | A | 37.2 | 36.7 | 37.2 | 36.7 | 33.5 | 33.5 | 35.1 | 33.3 | 78.6* |
| 7 | A | 37.1 | 36.6 | 37.1 | 36.5 | 33.2 | 34.2 | 35.1 | 33.2 | 74.2* |
| 5 | C | 37.0 | 36.5 | 37.0 | 36.4 | 34.1 | 34.3 | 35.1 | 32.8 | 54.5** |
| 6 | C | 37.1 | 36.6 | 37.1 | 36.5 | 33.7 | 34.1 | 35.1 | 33.5 | 75.0* |
| 4 | B | 36.9 | 36.5 | 36.9 | 36.4 | 33.6 | 34.5 | 34.6 | 33.6 | 61.6* |
| | | Subject #2 | | | | | | | | |
| 1 | P | 37.1 | 36.1 | 37.1 | 36.0 | 33.3 | 33.5 | 34.6 | 33.3 | 46.6 |
| 2 | P | 36.8 | 35.4 | 36.8 | 35.9 | 34.2 | 33.0 | 34.9 | 33.0 | 41.4 |
| 3 | C | 37.2 | 36.1 | 37.2 | 36.1 | 34.2 | 33.7 | 34.7 | 33.4 | 34.9* |
| 7 | C | 37.0 | 36.1 | 37.0 | 36.1 | 33.9 | 33.8 | 34.6 | 33.5 | 48.3* |
| 4 | A | 37.0 | 36.1 | 37.0 | 36.0 | 33.5 | 34.1 | 34.6 | 33.5 | 54.2* |
| 6 | A | 37.3 | 36.0 | 37.3 | 35.9 | 34.0 | 34.2 | 35.1 | 34.0 | 47.7* |
| 5 | B | 36.8 | 36.0 | 36.8 | 35.9 | 34.2 | 33.4 | 34.8 | 33.4 | 47.7* |

* Total sweat loss would include an average of 7.5 gm/hr additional $H_2O$ loss retained in the garments.

** Value questionable due to estimated weight of vomitus lost while sick.

data in the table are arranged so that comparison of the values obtained in replicate runs can easily be seen. Statistical analysis of the data is not warranted by sample size and was not done. To complement the table and demonstrate the similarity of the overnight temperature profiles, plots of $T_{sk}$ and $T_{re}$ for 10 minute periods are presented in Figures 1 through 8 for both subjects for each ensemble condition. The data reveal an amazing similarity in both core and surface temperatures of the subjects, as well as in the overnight profiles. Subject 1 tended to exhibit a slightly higher $T_{sk}$, a lower overnight fall in $T_{re}$ (average drop of 0.5°C versus 1.0°C for Subject 2), and a greater net evaporative loss rate. No meaningful differences were observed either between the various ensembles or between suited and control temperature levels. Individual $T_{sk}$s ranged from 32.0° to 35.5°C overnight, except for a few brief transients above 35.5°C. Typically the $T_{sk}$ rose approximately 1°C during the first one or two hours of the experiments and then oscillated downward over the remainder of the night. The often quoted comfort value for $T_{sk}$ is 33.3°C; our subjects tended to run from 0.5° to 1.0°C higher temperatures during these experiments, including the control nights when they were sleeping under blankets. Blanket coverage was periodic and based upon individual preference, but it may have acted to minimize the temperature differences compared to the suited runs. The resultant temperatures from the suited runs therefore approximate nighttime comfort levels for these subjects.

The overnight depression in $T_{re}$ observed in all cases is typical and normally observed as the nocturnal portion of circadian patterns. The tendency for $T_{re}$ to bottom out around 0300 or 0400 hours and rise slightly

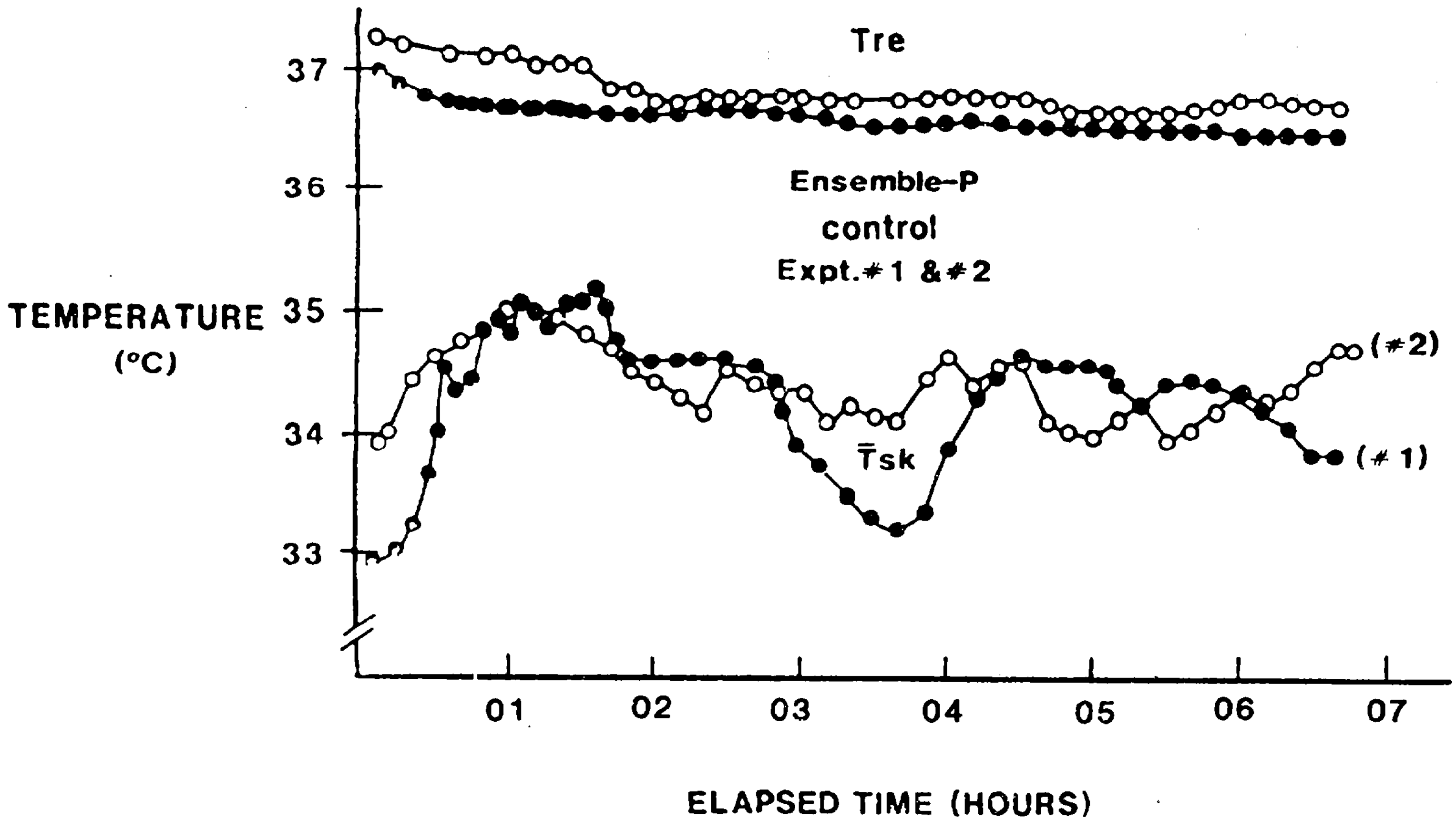



Figure 1. RECTAL TEMPERATURE (Tre) AND MEAN SKIN TEMPERATURE (T̄sk)

SUBJECT #1

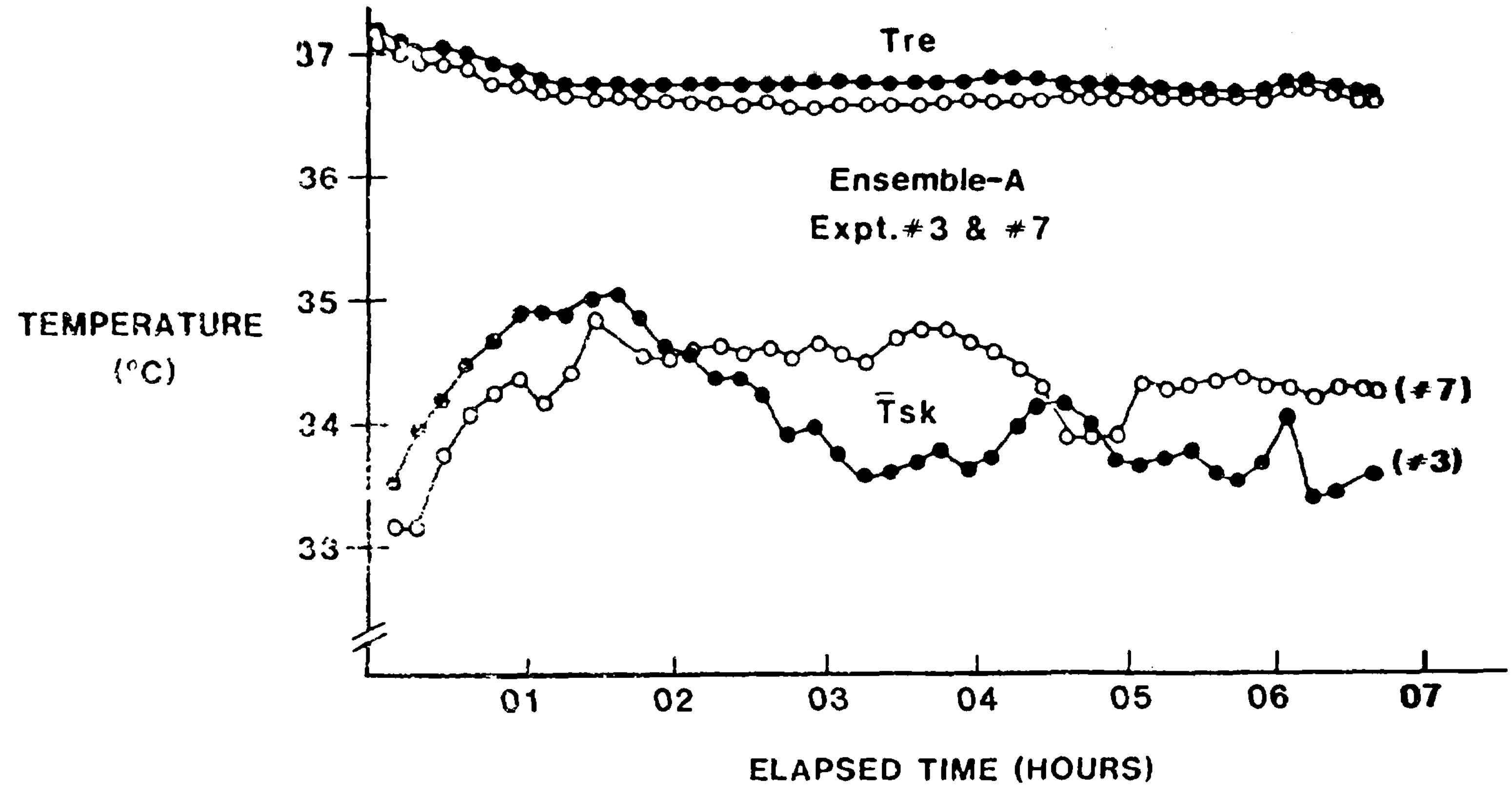



Figure 2. RECTAL TEMPERATURE (Tre) AND MEAN SKIN TEMPERATURE ($\bar{T}sk$)

SUBJECT #1

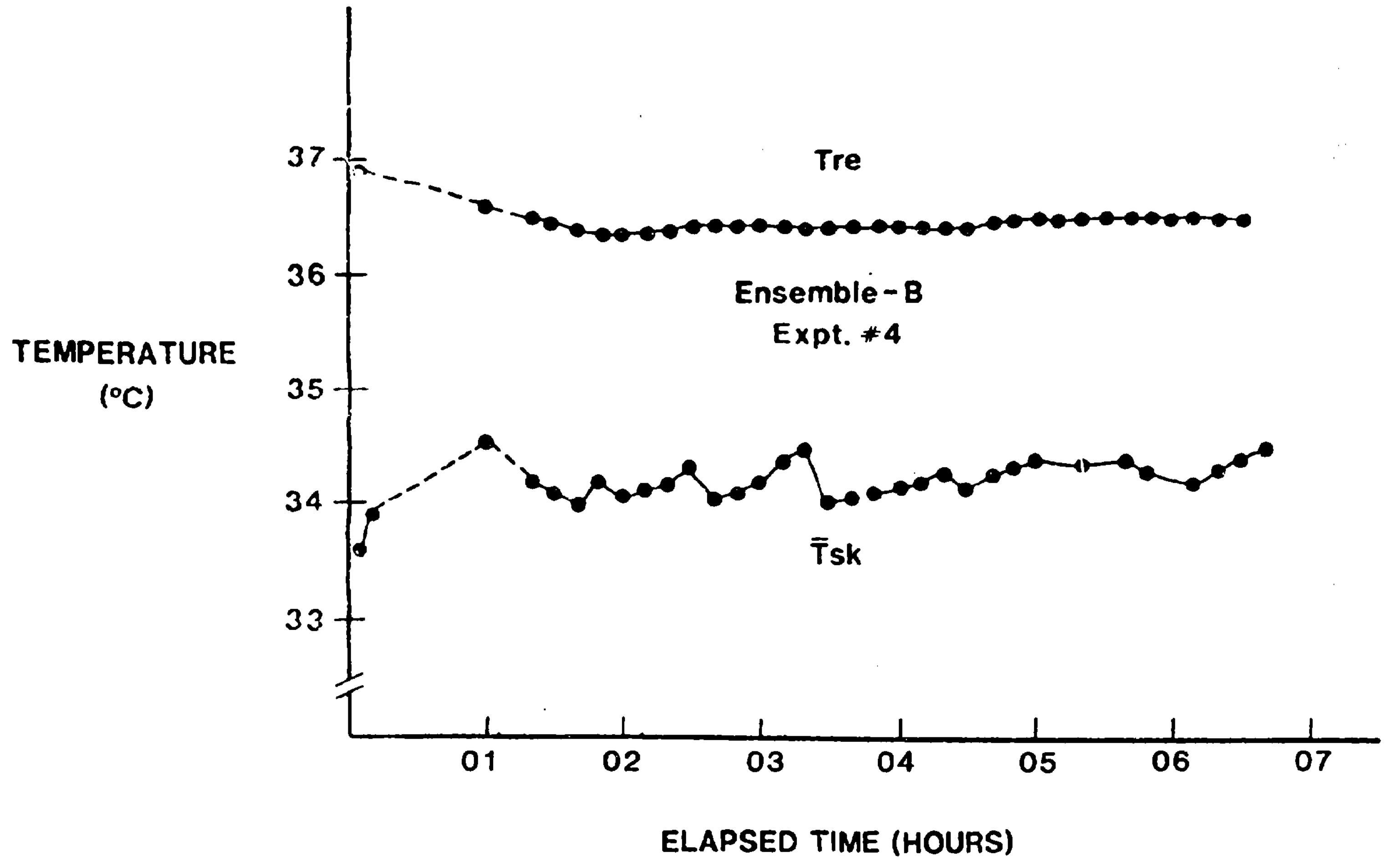



Figure 3. RECTAL TEMPERATURE (Tre) AND MEAN SKIN TEMPERATURE (T̄sk)

SUBJECT #1

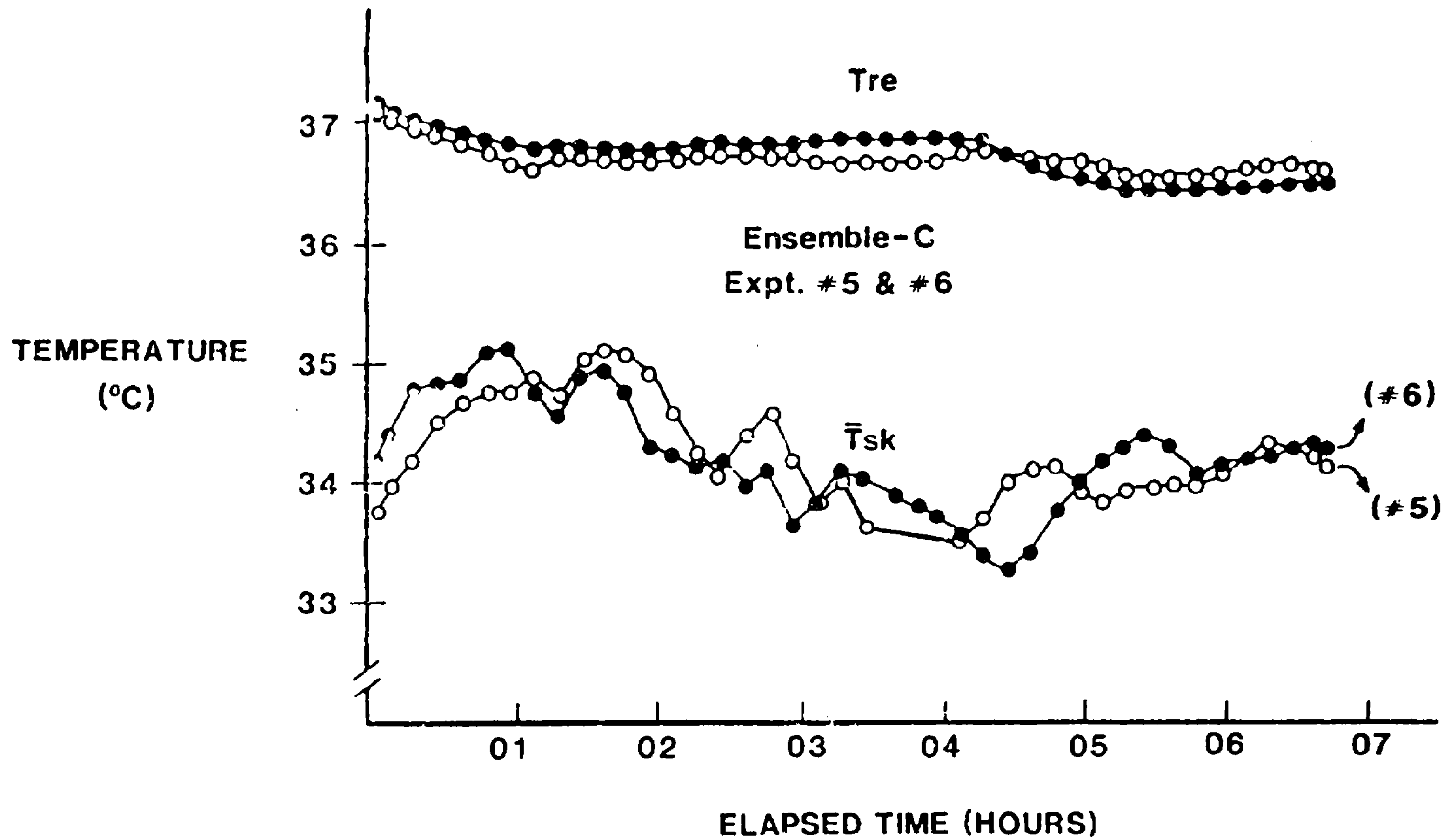



Figure 4. RECTAL TEMPERATURE (Tre) AND MEAN SKIN TEMPERATURE ($\bar{T}sk$)

SUBJECT #1

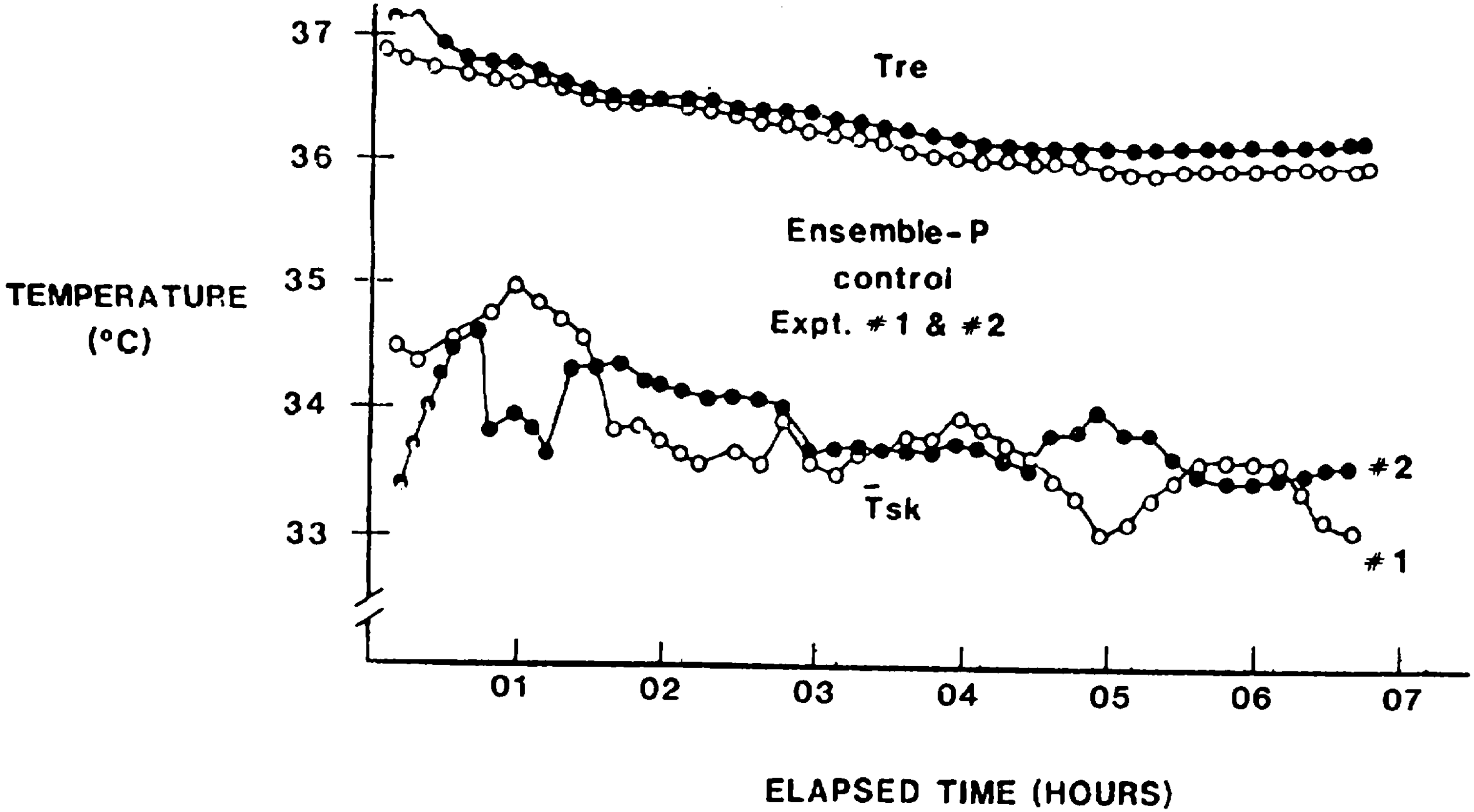



Figure 5. RECTAL TEMPERATURE (Tre) AND MEAN SKIN TEMPERATURE ($\bar{T}sk$)

SUBJECT #2

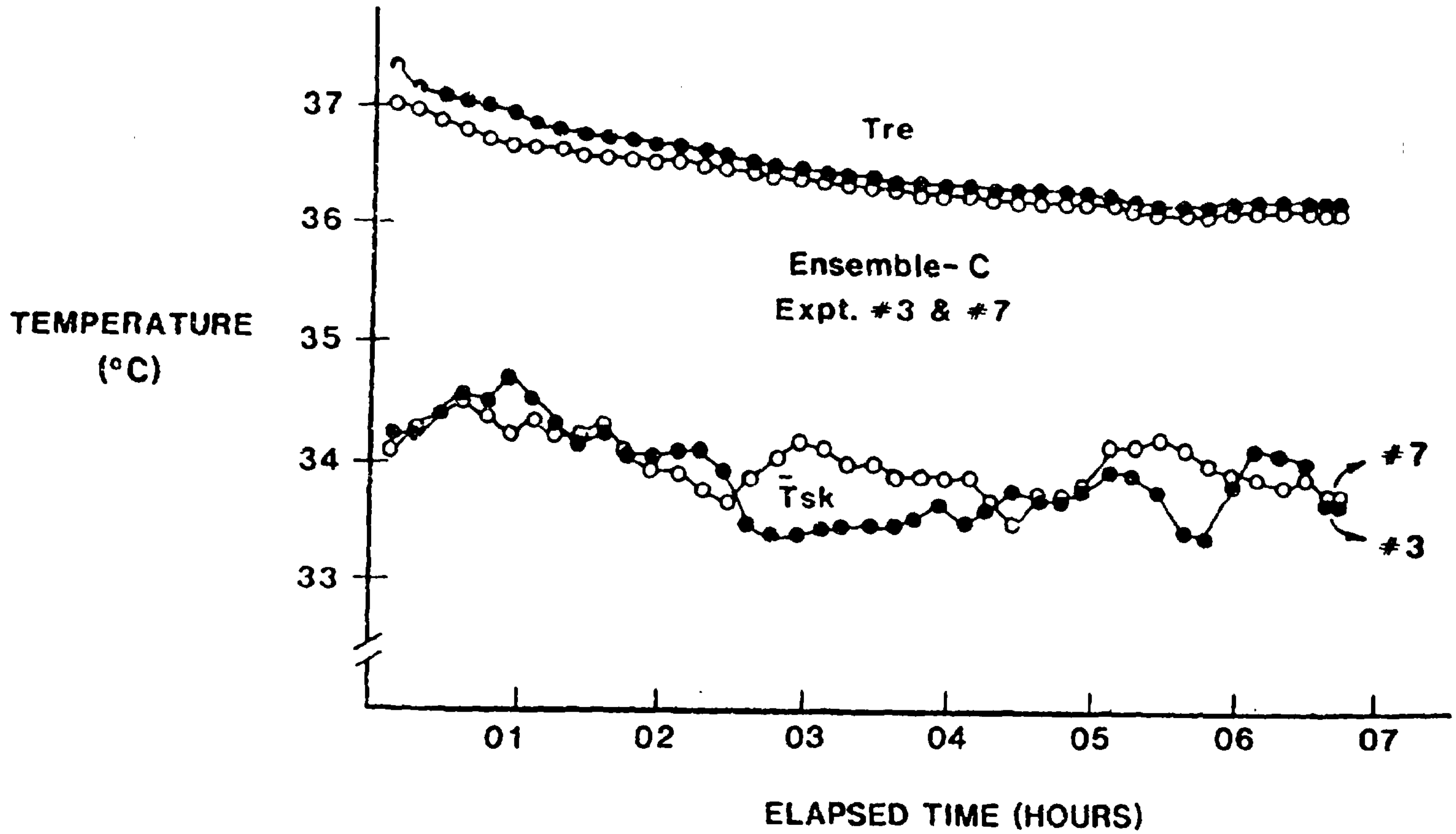



Figure 6. RECTAL TEMPERATURE (Tre) AND MEAN SKIN TEMPERATURE (T̄sk)

SUBJECT #2

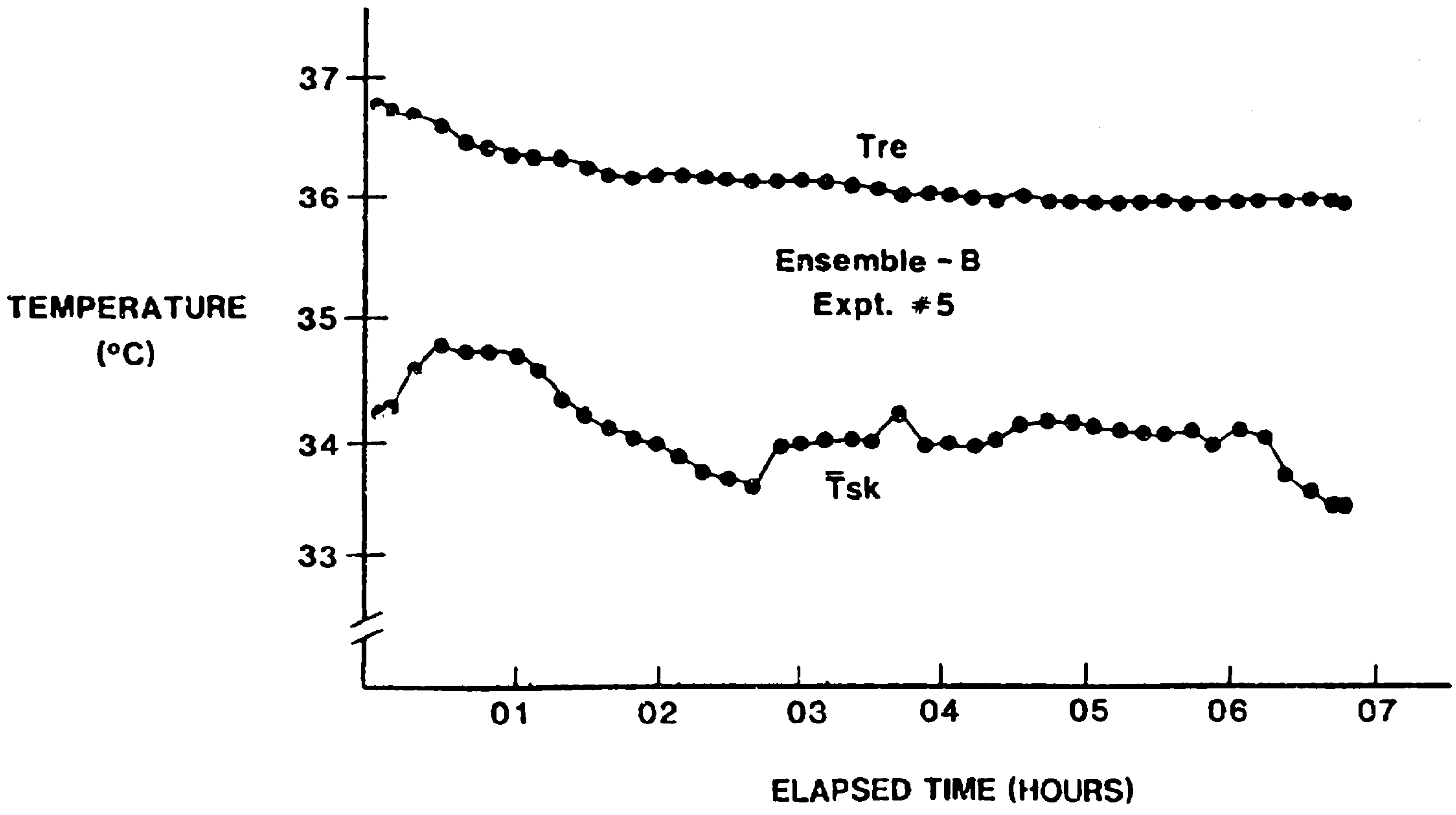



Figure 7. RECTAL TEMPERATURE (Tre) AND MEAN SKIN TEMPERATURE (T̄sk)

SUBJECT # 2

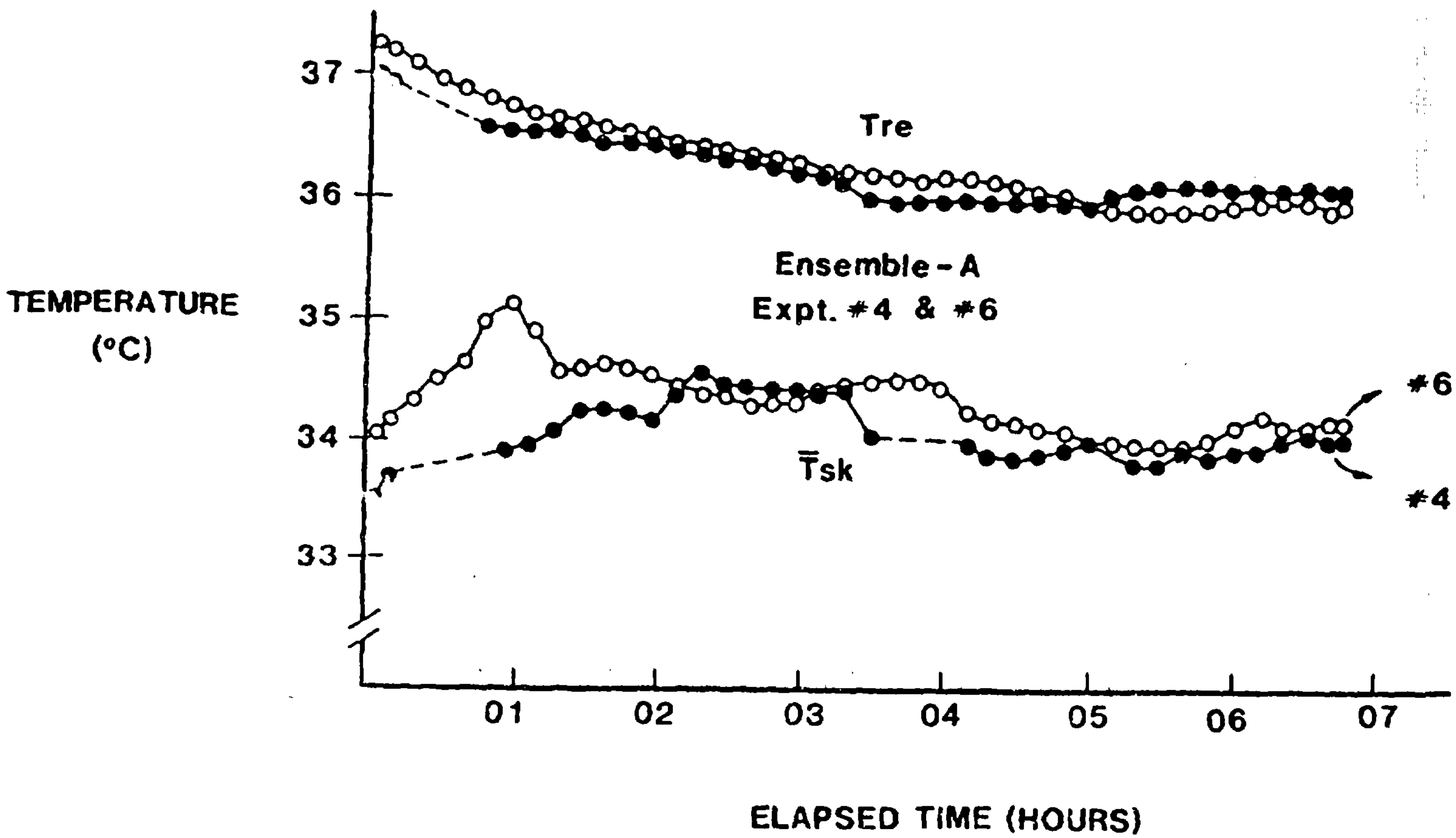



Figure 8. RECTAL TEMPERATURE (Tre) AND MEAN SKIN TEMPERATURE ($\overline{T}sk$)

SUBJECT #2

thereafter until wake-up is also normal. The low metabolic levels during sleep helped to make these experimental conditions tolerable. Work associated with normal Army duties, or combat, would no doubt present quite a different picture in thermal responses when the soldier was wearing any CPE.

The fact that the test environment must be described as thermally tolerable does not mean that the subjects were always comfortable, even though they may have been able to rest more comfortably than they would in the field since combat boots were not worn. The subjects frequently complained about the gloves, respirators, and hoods; particularly those of the U.S. ensemble. An accumulation of sweat on the hands and on the head and neck area added to the discomfort. Sweat running into the eyes was common and hard to deal with, particularly when the subjects were wearing the M17A1. Because of complaints of thermal discomfort when the M6A2 hood was worn, a thermistor was positioned in the crown area under the hood during experiment 7 (Subject 2), and this temperature was monitored periodically using manual techniques. The temperature inside the hood ran approximately 1°C higher than any skin temperature. The undergarments and the inner surface of the CPEs were routinely damp in the morning, even though the amount of retained moisture was not remarkably high. This discomfort was most evident when subjects were wearing the rubberized components. No evidence of charcoal "washout" with the impregnated garments was observed for any of the ensembles. Any estimate of environmental limits for soldiers sleeping in CPEs is not justified on the basis of this brief series of experiments.

## Sleep records

Sleep records were normally scored for each subject and each experiment in 30 second epochs. Since a complete experiment lasted 405 minutes, a total of 810 epochs per subject had to be examined for each experiment. Each subject was monitored once with 4-channel sleep records during one of the two control experiments, in addition to the normal 2-channel recordings taken during suited experiments. Thus for each subject there were six nights of sleep to be scored, five suited nights plus one control. Complete or nearly complete polygraphic records were obtained on 9 out of the 12 nights to be scored, including a complete 6 nights of good quality recordings on Subject 2. However, the control night (experiment 1) and portions of records from two other experiments (4 and 5) on Subject 1 were lost. About 30% (122 minutes) of the record from Subject 1 in experiment 4 was lost due to inking problems with the polygraph, and nearly 10% (40 minutes) of experiment 5 was lost while the subject was undergoing the nausea and vomiting described above.

Using standard terminology, the summary results of the sleep record scoring are presented in digital form in Table 6. The total time (minutes/night) spent in various stages of sleep, as well as the percentage each equals of the scored record, are given. The sleep latency periods--from lights out until Stage 1 sleep begins--are also given. The data are separated for each subject and individually grouped by replicate experiments.

## Table 6. SLEEP RECORD SUMMARY

| Expt. # | Clothing ensemble | Total Time Scored mins | TSW[4] mins | %SW % | TS1 mins | %S1 % | TS2 mins | %S2 % |
|---|---|---|---|---|---|---|---|---|
| | | | Subject #1 | | | | | |
| 1[1] | P | 387 | 11 | 2.8 | -- | -- | -- | -- |
| 3 | A | 402 | 72 | 17.9 | 183 | 45.5 | 70 | 17.4 |
| 7 | A | 405 | 19 | 4.7 | 74 | 18.3 | 204 | 50.4 |
| 5[2] | C | 215 | 157 | 73.0 | 16 | 7.3 | 11 | 5.1 |
| | C' | 150 | 7 | 4.7 | 6 | 4.0 | 69 | 46.0 |
| 6 | C | 400 | 33 | 8.2 | 127 | 31.7 | 156 | 39.0 |
| 4[3] | B | 283 | 3 | 1.1 | 97 | 34.3 | 125 | 44.1 |
| | | | Subject #2 | | | | | |
| 2 | P | 398 | 11 | 2.8 | 29 | 7.3 | 215 | 54.0 |
| 3 | C | 403 | 17 | 4.2 | 129 | 32.0 | 197 | 48.9 |
| 7 | C | 400 | 60 | 15.0 | 159 | 39.8 | 140 | 35.0 |
| 4 | A | 399 | 11 | 2.8 | 132 | 33.1 | 203 | 50.9 |
| 6 | A | 405 | 35 | 8.6 | 122 | 30.1 | 208 | 51.4 |
| 5 | B | 405 | 11 | 2.7 | 132 | 32.6 | 227 | 56.1 |

[1] Sleep record unsatisfactory for scoring; latency and stage W times derived from EMG record.

[2] Subject sick; 40 minutes lost while subject disconnected; 58.9% of night with M-17 on and 41.1% of night with no M-17 (C').

[3] Total record not scorable due to polygraph inking problems.

[4] Symbols used for labelling the various sleep stages are as follows: T = total time; S = stage; W-1-2-R-3-4 = the scored level; and % = $TS_X$/total time scored x 100.

Table 6. SLEEP RECORD SUMMARY (Cont)

| Expt. # | Clothing ensemble | Total Time Scored mins | TSR[4] mins | %SR % | TS3 mins | %S3 % | TS4 mins | %S4 % | Sleep Latency mins | Sleep Latency % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Subject #1** | | | | | |
| 1[1] | P | 387 | -- | -- | -- | -- | -- | -- | 30 | 7.8 |
| 3 | A | 402 | -- | -- | 14 | 3.5 | 33 | 8.2 | 31 | 7.5 |
| 7 | A | 405 | -- | -- | 20 | 4.9 | 73 | 18.0 | 15 | 3.7 |
| 5[2] | C | 215 | -- | -- | 19 | 4.2 | 7 | 3.2 | 15 | 6.9 |
| | C' | 150 | -- | -- | 11 | 7.3 | 51 | 34.0 | 6 | 4.0 |
| 6 | C | 400 | -- | -- | 19 | 4.8 | 19 | 4.8 | 46 | 11.5 |
| 4[3] | B | 283 | -- | -- | 15 | 5.3 | 11 | 3.9 | 32 | 11.3 |
| | | | | | **Subject #2** | | | | | |
| 2 | P | 398 | 49 | 12.3 | 21 | 5.3 | 51 | 12.8 | 22 | 5.5 |
| 3 | C | 403 | -- | -- | 31 | 7.7 | 0 | 0 | 29 | 7.2 |
| 7 | C | 400 | -- | -- | 15 | 3.8 | 12 | 3.0 | 14 | 3.5 |
| 4 | A | 399 | -- | -- | 18 | 4.5 | 13 | 3.2 | 22 | 5.5 |
| 6 | A | 405 | -- | -- | 30 | 7.4 | 1 | 0.2 | 9 | 2.2 |
| 5 | B | 405 | -- | -- | 28 | 6.9 | 0 | 0 | 7 | 1.7 |

1 Sleep record unsatisfactory for scoring; latency and stage W times derived from EMG record.

2 Subject sick; 40 minutes lost while subject disconnected; 58.9% of night with M-17 on and 41.1% of night with no M-17 (C').

3 Total record not scorable due to polygraph inking problems.

4 Symbols used for labelling the various sleep stages are as follows: T = total time; S = stage; W-1-2-R-3-4 = the scored level; and % = $TS_X$/total time scored x 100.

Bar graphs showing the cumulative time spent in the various stages (minutes/night/stage) are presented in Figures 9 and 10 for Subjects 1 and 2 respectively. The shaded portion of the W bar (time awake) represents the sleep latency period for each experiment. Experiment 5 on Subject 1 wearing ensemble C (with M17) has been divided into the period before (215 minutes) and the period after (150 minutes) the time when the subject was disconnected from the monitoring equipment, in both Table 6 and Figure 9. The M17 mask was the only component of ensemble C (labeled C' on Table 6) not worn following the disconnected period.

It is difficult to assess the qualitative aspects of the sleep records using the basic quantitative data presented in Table 6 and Figures 9 and 10. Pertinent questions to be answered are:

a. How did the control night of sleep compare with those in the ensembles

b. Were there significant improvements when the first suited night (experiment 3) and the last suited (replicate) night (experiment 7) results were compared

c. Was any one of the CPEs clearly superior, as judged from sleep records

d. How did the replicate experiments compare to each other?

In order to simplify obtaining answers to these questions, certain parameters were summarized from the basic data, and these are presented in Table 7. The variables selected for analysis were: sleep latency; times awake; and total time spent per night in slow wave, or delta, sleep (sum of stage 3 and stage 4). The data are grouped by ensemble, subject, and replicate experiments.

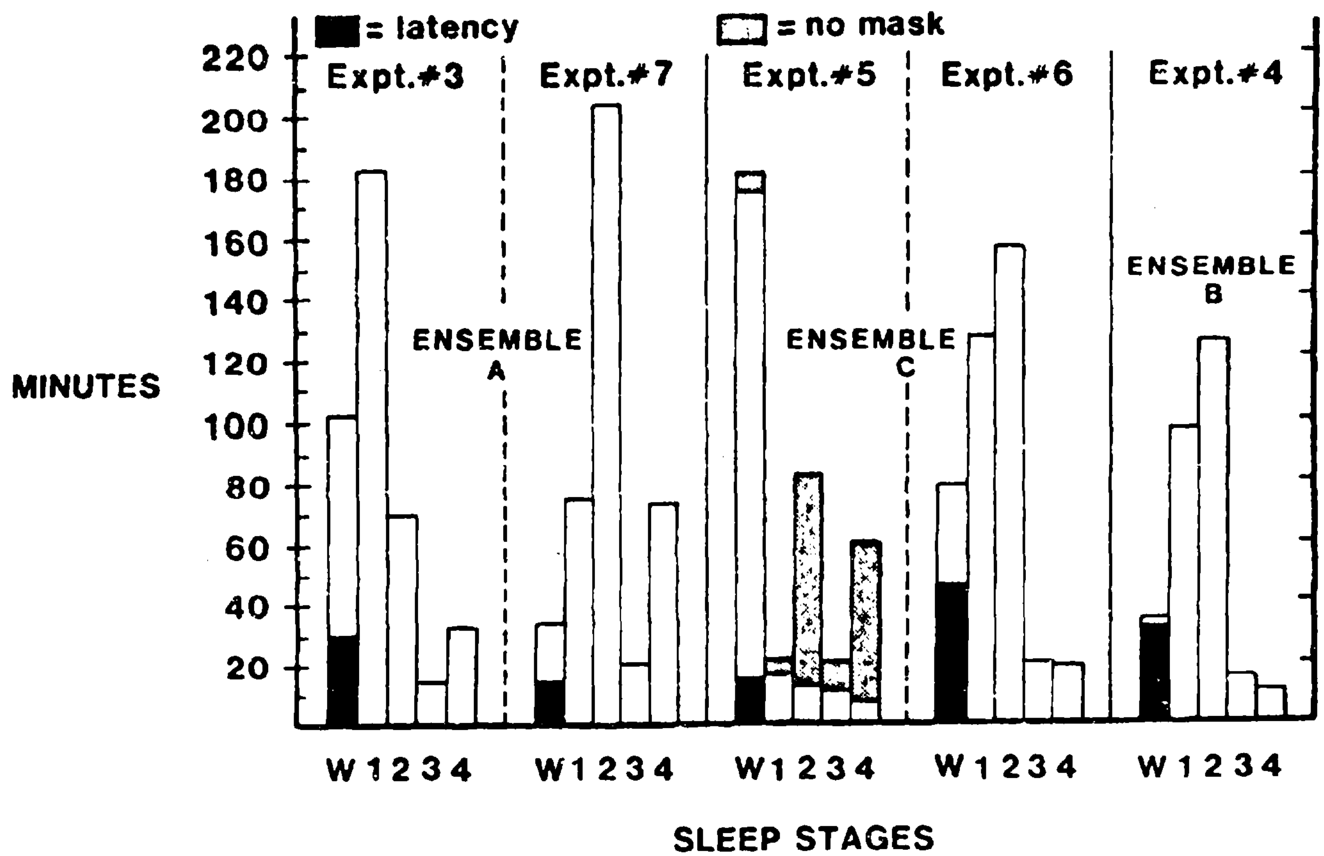



Figure 9. CUMULATIVE SLEEP BY STAGE
SUBJECT #1

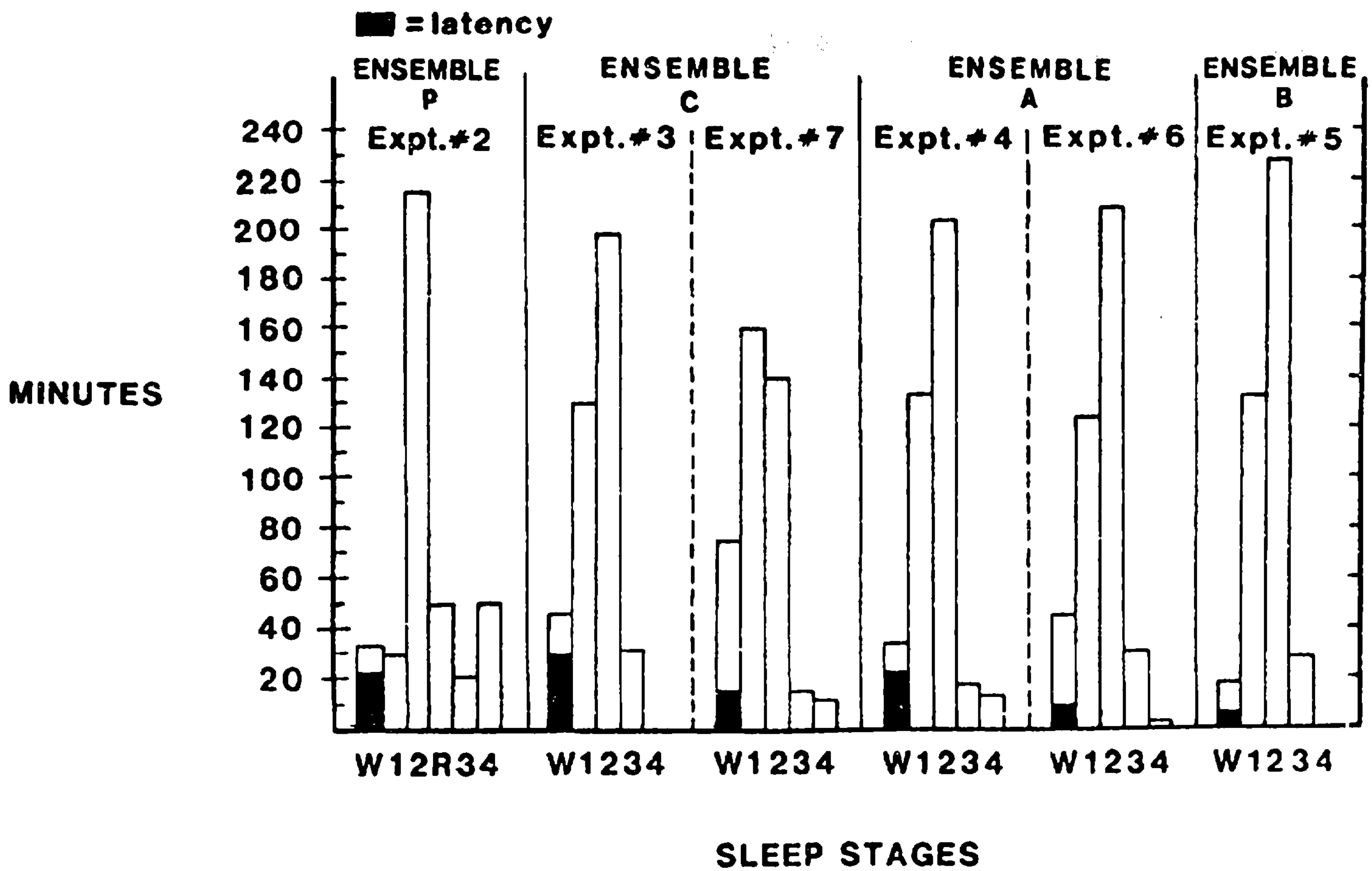



Figure 10. CUMULATIVE SLEEP BY STAGE

SUBJECT #2

Table 7. SUMMARY OF THE SLEEP RECORDS, SHOWING LATENCY, TIMES AWAKE, AND TOTAL DELTA SLEEP TIME (TS3 & TS4)

| Clothing Ensemble | Subj. | Expt.# | Total Time Scored (minutes) | Latency (minutes) | Times Awake[1] > 30 secs,# | Combined TS3 & TS4 (minutes) |
|---|---|---|---|---|---|---|
| P | 1 | 1 | 387 | 30 | 9 | -- |
| | 2 | 2 | 398 | 22 | 7 | 72 |
| A | 1 | 3 | 402 | 31 | 9 | 47 |
| | | 7 | 405 | 15 | 14 | 93 |
| | 2 | 4 | 399 | 22 | 8 | 31 |
| | | 6 | 405 | 9 | 16 | 31 |
| B | 1 | 4 | 283 | 32 | 8 | 26 |
| | 2 | 5 | 405 | 7 | 12 | 28 |
| C | 1 | 5[2] | 215 (w/M17) | 15 | 11 | 17 |
| | | | 150 (no M17) | 6 | 1 | 63 |
| | | 6 | 400 | 46 | 15 | 38 |
| | 2 | 3 | 403 | 29 | 9 | 31 |
| | | 7 | 400 | 14 | 20 | 27 |

[1] Does not include latency period.

[2] Experiment is divided into the period prior to sickness during which time the subject wore the M17 most of the time (w/M17) and after vomiting when no M17 was used (no M17).

Whether the amount of time spent falling asleep was more related to an initial feeling of comfort in a given ensemble or to a variety of psychophysiological factors is debatable; however, sleep latency time has been included here as support for qualitative judgment . The scoring of latency, as previously stated, was based upon the presence of alpha activity combined with high tonic EMG levels, except for experiment 1 on Subject 1 when the EEG was not available. For this experiment, latency was scored, as well as times awake, on the basis of high tonic EMG and obvious periodic movement. Latency was reduced in the second experimental night in three out of four replicates. The fourth replicate experiment (Subject 1, experiment 5, ensemble C) cannot be included due to the sickness episode. The latency periods on first nights with CPEs compared favorably with control levels; however, the second night replicates do show a substantial reduction in latency, suggesting that a subjective adjustment took place. There was no evidence of superiority of any particular CPE in this regard. The noticeably longer latency in experiment 6 for Subject 1 wearing ensemble C was primarily due to seal difficulties associated with the M17A1 mask.

The number of times awake was always greater on the second night for the replicate experiments, whereas the first nights compared favorably with control numbers. No discernible difference was noted when the different CPE were compared. Why the subjects were awake more times on the second night in a given ensemble cannot be explained.

Perhaps a more useful criterion for qualitative assessment of sleep is the amount of time spent in stage 3 and stage 4 (delta or slow wave) sleep. The times for stages 3 and 4 combined are given in Table 7. Because of the

lack of a control EEG record on Subject 1, comparison of nights in the CPEs versus control level cannot be made. Intercomparison of nights in CPEs for this subject is made more difficult because of the events of experiment 5. Nevertheless, the stage 3 and stage 4 time for this subject in experiment 7 was double that for his first night in ensemble A. probably not due to any training effect, particularly for this subject, but rather due to psychological factors associated with the "last experiment" effect. Also, it is worth noting that following the sickness episode the subject spent 63% of the time in slow wave sleep, an extremely high proportion. This is probably more related to his poor sleep earlier in the night than to the fact that he was not wearing the M17.

Since essentially complete sleep records were available for Subject 2 for all experimental conditions, intercomparative judgements are more reliable. First, the stage 3 and stage 4 times for all suited experiments were essentially identical, whether first night or replicate. Therefore, no effect due to ensemble or training on this qualitative aspect was observed, and indeed the quantitative similarity is truly remarkable. The large reduction in slow wave sleep compared to control level is also surprising, and is perhaps a reliable index of the effect of CPEs on sleep--at least for one individual.

Using primarily the data from Subject 2 as a base, and with emphasis on the amount of slow wave sleep, the following tentative conclusions are offered:

a. The amount of slow wave sleep is reduced when wearing CPEs

b. The amount of time awake overnight when wearing CPEs may or may not be increased over control levels

c. No clear superiority can be assigned to a particular CPE so far as not interfering with sleep is concerned

d. No evidence of training effect from first to last night was observed

e. Despite the potentially disruptive effects of a brief series of overnight experiments, regardless of clothing worn, these subjects reported that they were generally able to perform their jobs effectively the day following an experiment.

The disruptive effects of the combat scenario were minimal throughout the test series. This conclusion is based upon assessment of stage W production from the sleep records as well as upon statements made by the subjects. Using the criteria established for the assignment of true wakefulness, i.e. 30 seconds of high tonic EMG with or without alpha activity; the subjects were not consistently awakened following the 20 seconds of noise regardless of dB level, time of night, or stage of sleep at the time. It is true, however, that both men commonly displayed a "startle" (high tonic EMG lasting less than 30 seconds) following the highest noise bout (105 dB). Because this level was used early in the night when Stage 3 or Stage 4 was most common, return to preexisting level was usually rapid. Reactions to the intermediate dB levels were mixed but usually the last noise bout (92 dB at 0500), when sleep level was stage 1 or stage 2, was most disruptive. In all but two experiments (experiment 7, Subject 1; experiment 4, Subject 2), the subjects were awake for 2 to 5 minutes following the 0500 noise bout. The fact that both occasions when the subjects were not truly awakened occurred in association with ensemble A was probably coincidental.

### Other physiological measurements

Heart rates were monitored throughout each experiment. Usually the rates were counted from the R spikes which were superimposed on the EMG tracings. Typically, heart rates for both men ran approximately 70 beats/min while awake, but dipped into the high 50's (55-58 beats/min) while they were sleeping. During most of each night, rates of 60-65 beats/min were common. These rates are not atypical for men of these subjects' age, particularly men of modest fitness levels. During times of extreme quiet, i.e., low tonic EMG levels, almost pure electrocardiographic patterns were discernible on the EMG channel. Other than an occasional premature ventricular contraction, no other meaningful evidence of overnight arrhythmia was observed. As a safety measure, the heart rate signals helped to assure the well being of the subjects. It was this measurement, combined with the high tonic EMG, that led to the discovery of the impending illness of Subject 1 during experiment 5. The subject had not communicated his suspicions to the monitor even though a live microphone lay nearby and the subjects had been instructed to use it in case of any difficulty.

Respirator seal integrity was monitored on a time-sharing basis via measurement of the $CO_2$ level within the oronasal area of the masks. Analysis of these data disclosed an average elevation of approximately 0.10% $CO_2$ under proper conditions of sampling. During experiment 3, cyclic variations ranging from 0.0% to 5.0% $CO_2$ were observed with the West German mask (Subject 1). It was concluded that the variations were associated with breathing and that almost pure expired air was being sampled from time to time due to the placement of the sample line within the oronasal area. The placement of the sample line was altered for the later experiments and

stable $CO_2$ levels were obtained. Use of the drinking tube line in the M17A1 was generally satisfactory as a sampling location; however, occasionally cyclic variations in $CO_2$ level were also observed.

The evidence clearly suggests that placement of the sample line port is critical if reliable indications of rebreathing are to be monitored. Results indicate that the West German mask tends to run 0.02% to 0.05% higher $CO_2$ levels than the M17A1 under the conditions used in these experiments. Furthermore, even though the subjects said that the M17A1 was the proper size, a good seal in the frontal area was very difficult to achieve. This was particularly true for the later experiments in which this mask was used (experiment 6, Subject 1, and experiment 7, Subject 2). Prompted more by the EMG evidence than by $CO_2$ level, the monitor entered the test chamber several times during these nights to render assistance to the subjects. The sleep records tend to verify the difficulties the subjects experienced (see Table 7, especially sleep latency for Subject 1, experiment 6, and times awake for Subject 2, experiment 7). Post-experiment examination of the mask disclosed a frontal midline crease which apparently had resulted from long-term storage in the mask carrier. Both subjects felt that the size of the mask had been increased.

In conclusion, the monitoring of oronasal $CO_2$ is a questionably useful indicator of mask seal integrity, and the levels observed are more related to sample port location than to rebreathing.

**Debriefing questionnaire**

Each morning following an experiment, the subjects completed a questionnaire designed to evaluate their feelings about how well they had

slept and the ensemble they had worn the night before. The actual questionnaire, along with the total responses and the frequency related to a given ensemble, is shown in Table 8. The individual responses of each subject following each experiment are given in Appendix A.

In general, the subjects felt that they had slept less well than they would have at home (8 of 14 responses), although Subject 1 reported once that he had slept better than at home (ensemble B). Three times the subjects reported that they had slept badly (Question 1-d), all while wearing the U.S. ensemble. They reported being sleepy and not well rested (Question 2-c), or having slept badly compared to the previous night (Question 3-d) only after having worn the U.S. ensemble. In addition, they did not feel alert or ready for a day's work (Question 10-no) on three occasions, all following a night in the U.S. ensemble. The subjects reported that it took them an average of nearly 43 minutes to fall asleep (Question 7), with a range from 15 to 180 minutes, although the actual sleep latency was only 23 minutes. The most frequent estimation by the subjects was 30 minutes (4 times). The 180 minutes estimated by Subject 2 for experiment 7, wearing ensemble C, was much greater than his actual sleep latency time due to the difficulties he was having with the seal on the M17A1 mask, and also because of the many times that he was awake during the night. For all the experiments, the subjects estimated that they were awake (Question 9) from 2 to 7 times a night, with an average frequency of over 4 times a night, although the average from the sleep records was over 11 times per night. The largest number of estimated times awake was associated with the first control night (Subject 2), which is not surprising. The intermediate estimates of times awake were about evenly distributed

Table 8. SUMMARY OF DEBRIEFING QUESTIONNAIRE

(No. of answers to each question, both subjects; ensemble specified by letter)

1. How well did you sleep last night? Compare to a normal night at home.

   a. Better-- 1 (1-B)
   b. As good as--2 (1-C;1-A)
   c. Below average--8 (3-P; 3-A; 1-B; 1-C)
   d. Badly--3 (3-C)

2. How do you feel now, despite how well you slept?

   a. Well rested--3 (1-P; 1-A; 1-B)
   b. Not well rested, but not sleepy--8 (3-P; 3-A; 1-B; 1-C)
   c. Not well rested, and sleepy--3 (3-C)

3. How did last night's sleep compare to the previous night's?

   a. Better than-- 0
   b. As good as--6 (1-P; 3-A; 2-B)
   c. Below average--6 (3-P; 1-A; 2-C)
   d. Badly--2 (2-C)

4. What were the best and worst features of ensemble? (specify)

   a. Best features: mask seal--1 (1-A); unipiece--1 (1-B); freedom of movement--1 (1-C)
   b. Worst features: gloves--4 (2-A; 1-B; 1-C); mask--3 (3-C); rectal probe--1 (1-P); instrumentation--1 (1-P); fit--4 (1-A; 1-B; 2-C); thermal--1 (1-C).

5. What would you change about last night's ensemble? (specify briefly)

   Rectal probe--2 (2-P); too hot--1 (1-C); gloves--3 (1-A; 1-B; 1-C); mask--2 (2-C); garment fit--2 (2-B); boots--1 (1-C); nothing--1 (1-A).

6. What bothered you most about the items listed below?

   Uniform--2 (1-B; 1-C); mask--5 (1-A; 4-C);environment--0; noise--1 (1-P); hood--0; gloves--6 (2-A; 2-B; 2-C); instrumentation--1 (1-P).

7. About how long did it take to fall asleep last night? (estimate minutes)

   15--3 (1-P; 1-A; 1-C); 20--1 (1-C); 25--1 (1-P); 30--4 (2-P; 1-A; 1-B); 45--2 (1-B; 1-C); 60--2 (2-A); 180--1 (1-C). Range=15-180 minutes.

Table 8. SUMMARY OF DEBRIEFING QUESTIONNAIRE (Cont)

8. Do you recall dreaming last night?

   yes--1 (1-A); no--13 (all other).

9. How many times did you awaken last night? (estimate number of times)

   1--0; 2--2 (1-A; 1-C); 3--1 (1-P); 4--4 (2-A; 1-B; 1-C); 5--2 (1-P; 1-B); 6--3 (1-P; 1-A; 1-C); 7--1 (1-P).

10. Do you feel alert and ready to do a day's work?

    yes--11 (4-P; 4-A; 2-B; 1-C); no--3 (3-C).

among the various ensembles. The subjects recalled dreaming (Question 8) on only one occasion (Subject 1, experiment 3, ensemble A).

In response to those questions (4, 5, and 6) dealing with specific negative features or items of an ensemble and/or the experimental procedures, the most frequently mentioned articles were the masks, gloves, and clothing fit. Subject 2 disliked wearing either type of glove provided. Twice the monitor discovered that this subject had removed the gloves during the night (experiment 3, ensemble C, and experiment 5, ensemble B). Both times the subject said that he could not recall having removed the gloves. The subjects expressed displeasure with the U.S. respirators; this was primarily related to the suspected contamination and subsequent illness (Subject 1, experiment 5; M17); and to the seal difficulties experienced in experiments 6 and 7 by Subjects 1 and 2 while wearing the M17A1.

The major fit or sizing problems reported for the articles of clothing were the following:

a. Ensemble A: blouse too tight on chest and head movement restricted by hood (experiment 3, Subject 1).

b. Ensemble B: coverall too tight in crotch (experiment 4, Subject 1, and experiment 5, Subject 2).

c. Ensemble C: gloves too tight and hot (experiments 3 and 7, Subject 2).

The subjects, with the help of the investigator, did select combinations of items which appeared to fit best from those supplied for the various ensembles; however, it must be remembered that better overall fit could probably have been achieved had all sizes been available for each ensemble component.

## DISCUSSION

A brief pilot study such as the one described here usually raises more questions than it answers. This series of experiments is no exception; however, three questions were answered in a preliminary fashion. First, thermal burden is minimal at 25°C room temperature, as evidenced by the body temperature data and the tolerable increase in sweat loss. Second, men are able to sleep comparatively well while wearing properly fitted CPEs under moderate environmental conditions. Third, short term and infrequent noise up to 105 dB levels does not act to disrupt sleep grossly regardless of sleep level. Under conditions of greater potential heat stress and more frequent or greater noise intensity, probably none of the above statements could be made. Under what levels of environmental stress these factors become truly disruptive can only be speculated on at the present time. It is clear that the effect of environmental stresses will amplify those subjective factors associated with the use of CPE's.

A number of findings related to the functional characteristics of the ensembles can be mentioned. Although specific items will be named, it is believed that these general aspects could apply to any of the ensembles. Some of these findings are:

a. Dishevelment of clothing following a night of sleep was common. Whether or not the extent of the dishevelment was sufficient to imply impending hazard to a combat soldier under chemical attack cannot be stated. Most commonly, the attached hood associated with the A and B ensembles was loose and gapping in the morning. The U.S. M6A2 hood did appear to retain secure positioning over-

night. Two-piece body garments (A and C) did not seem to gap at the waist in the morning; however, the neck closure on B showed evidence of unconscious loosening after both nights it was worn.

b. Gloves were unconsciously removed overnight on three occasions. The M17A1 respirator was totally removed on one occasion. When the monitor entered the chamber, the mask was lying on the chest of Subject 2, and the $CO_2$ level had given no evidence of removal. The implication is that unconscious total removal of articles of clothing and/or respirators will occur in sleeping soldiers with surprising frequency.

c. The design and fit of respirators do not appear to affect grossly $CO_2$ level buildup from rebreathing; however, seal integrity did act to disrupt sleep on two occasions.

d. The most frequent complaints included the gloves, the respirators, and the hoods.

e. No clear superiority can be assigned to different types of closures, but the adjustability associated with Velcro type closures was preferred by the subjects.

f. Problems encountered in this series of experiments related to poor fit and equipment status probably could have been avoided if the full range of sizes had been available, with multiple components of each size.

In many ways, the experiments were conducted under ideal conditions. Conclusions based upon data analysis, subject comments, or observations of the monitor must therefore be applied to combat conditions with caution. The subjects were experienced, well trained, and highly motivated, but they

were aware that their well being would be under constant observation and that there was no chemical threat. Under these conditions the results obtained were, perhaps, less than realistic.

Other factors acted to make interpretation of the results difficult. Too few experiments were conducted to determine whether such differences as were observed were the result of the influence of normal day-to-day variation in psychosocial and physiological factors or due to the particular CPE worn. Unfortunately, a good control sleep record on Subject 1 was not obtained, and portions of sleep records were lost during another experiment due to instrument problems. In two of the late experiments, the poor seal obtained with the M17A1, which appeared to have a permanent crease from prolonged storage in the carrier pouch, made sleep difficult for both subjects.

The unusual combination of items comprising ensemble B makes results obtained difficult to apply in a practical manner unless this combination is viewed as a potential NATO ensemble. The voluntary selection of the West German gloves and boots by the subjects reflected their stated preference for these items. Finally, the limited number of experiments generally limits statistical interpretations that are justified.

On the positive side, perhaps the noninstrumentational problems encountered are not unlike those which may occur under field conditions. For example, when the monitor assisted one subject, the disruptive effects on the second subject may be like those a soldier with a problem would have on a buddy trying to sleep nearby. Items of a standard issue ensemble will not fit better with any greater degree of regularity, and the typical soldier will not exhibit more reliable usage of equipment than the

subjects tested in these experiments. Therefore, the frequent incidence of potential failures experienced with the tested CPEs may not be unusual under combat conditions. Obvious failures (including removal of items) were mainly associated with the U.S. ensemble; however, this finding was clearly biased by the difficulties experienced with the M17 and M17A1 respirators. In summary, the implication of this brief study is that under conditions of a chemical attack lasting overnight, casualties may result regardless of the CPE used.

# CONCLUSIONS AND RECOMMENDATIONS

## Conclusions

a. Under moderate environmental conditions of temperature and vapor pressure, the CPEs tested did not produce evidence of meaningful thermal burden. Sweat rates were increased over control levels, but remained within tolerable limits. Subjective discomfort mainly involved sweat accumulation on the head and hands.

b. The amount of slow wave or delta sleep was reduced when CPEs were worn. Sleep latency and/or the number of times awake during the night were influenced most by difficulties associated with respirators.

c. Brief and infrequent bouts of white noise with a sound intensity of up to 105 dB do not seriously disrupt sleep. Some evidence suggested the relative effect to be greater during stage 1 or stage 2 sleep occurring toward morning.

d. Items of an ensemble will be totally, albeit unconsciously, removed by the sleeping individual. The gloves and the respirator are particularly prone to removal.

e. Persons are generally able to perform effectively on the job following a night in a CPE.

f. Correctness of fit and function of CPE items will probably be more critical during periods of sleep than when awake.

## Recommendations

### Current Equipment

a. Securing fasteners should be incorporated into the current mask and gloves to prevent unconscious removal of these components.

b. Other NATO respirators, such as the West German mask evaluated in this study, may be considered as near-term substitutes for the M17A1 series to offer improved overnight comfort.

### Follow-up Research

a. Ability of persons to sleep in CPEs should be tested under conditions that are likely to be thermally stressful.

b. Additional experiments involving a greater number of subjects would permit statistical comparison of various ensembles.

c. Preexperiment wear time should be extended in order to reproduce combat conditions better.

d. Tests should involve use of complete, unmixed ensembles, which have been carefully selected and fitted to the test subjects.

e. The test subjects should be selected randomly from active military personnel. The training and experience level should be equivalent to that provided during basic training.

f. Seal integrity should be tested at bedtime and upon awakening, using an acceptable method other than $CO_2$ monitoring.

g. Videotape or movie films could serve as a useful adjunct to the sleep record, if they can be obtained without disruptive effects.

h. If good quality EOG tracings can be obtained while wearing a full-face respirator, they should be added to the sleep record.

However, subject discomfort associated with a subseal electrode placement must be considered.

i. The effect of sleep deprivation, diet, and other modifying factors on the ability to sleep in CPEs should be examined.

j. A full record sleep evaluation should be conducted nonobtrusively in conjunction with a large-scale field test.

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# APPENDIX A

## Debriefing Questionnaires

DEBRIEFING QUESTIONNAIRE -- SUMMARY OF RESPONSES FOR ALL EXPERIMENTS

Subject #1

1. How well did you sleep last night? Compare to a normal night at home.

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. better-------- | | | | x | | | |
| b. as good as---- | | x | | | | | x |
| c. below average- | x | | x | | | x | |
| d. badly--------- | | | | | x | | |

2. How do you feel now?

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. well rested--- | | x | | x | | | x |
| b. not well rested; not sleepy---- | x | | x | | | x | |
| c. not well rested; sleepy-------- | | | | | x | | |

3. How did last night's sleep compare to the previous night's?

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. better than--- | | | | | | | |
| b. as good as---- | | x | x | x | | | x |
| c. below average- | x | | | | | x | |
| d. badly--------- | | | | | x | | |

DEBRIEFING QUESTIONNAIRE -- SUMMARY OF RESPONSES FOR ALL EXPERIMENTS (Cont)

Subject #1

4. What were the best and worst features of ensemble? (specify)

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. best features | | | mask seal | unipiece | | freedom of movement | mask easier to sleep in |
| b. worst features | | | shoulder-neck fit | size | M-17 | very hot inside | restrict movement |

5. What would you change about last night's ensemble? (specify briefly)

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| | | | nothing | use full Canadian assembly | use M-17 with extra set of filters | change boots and gloves | tight hood restricts head-neck movement |

6. What bothered you most about the items listed below? If you were not bothered, write in OK.

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. uniform------ | OK | OK | x | | | | OK |
| b. mask--------- | | | | | x | x | |
| c. environment | | | | | | | |
| d. noise-------- | | | | | | | |
| e. hood--------- | | | | | | | |
| f. gloves------- | | | x | x | | | |
| g. instrumentation | | | | | | | |
| h. other-------- | | | | | | | |

DEBRIEFING QUESTIONNAIRE -- SUMMARY OF RESPONSES FOR ALL EXPERIMENTS
(Cont)

Subject #1

7. About how long did it take to fall asleep last night? (estimated minutes)

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| | 25 | 30 | 60 | 30 | (sick) | 20 | 15 |

8. Do you recall dreaming last night?

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. yes------- | | | x | | | | |
| b. no-------- | x | x | | x | x | x | x |

9. How many times did you awaken last night? (estimate number of times)

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| | 6 | 7 | 6 | 4 | (sick) | 4 | 2 |
| How does your answer compare to normal? | -- | +1 | +3 | -- | | +2 | -- |

10. Do you feel alert and ready to do a day's work?

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. yes------- | x | x | x | x | | x | x |
| b. no-------- | | | | | x | | |

DEBRIEFING QUESTIONNAIRE -- SUMMARY OF RESPONSES FOR ALL EXPERIMENTS

Subject #2

1. How well did you sleep last night? Compare to a normal night at home.

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. better-------- | | | | | | | |
| b. as good as---- | | | | | | | |
| c. below average- | x | x | | x | x | x | |
| d. badly--------- | | | x | | | | x |

2. How do you feel now?

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. well rested--- | | | | | | | |
| b. not well rested; not sleepy---- | x | x | | x | x | x | |
| c. not well rested; sleepy-------- | | | x | | | | x |

3. How did last night's sleep compare to the previous night's?

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. better than--- | | | | | | | |
| b. as good as---- | | | | x | x | | |
| c. below average- | x | x | x | | | x | |
| d. badly--------- | | | | | | | x |

## DEBRIEFING QUESTIONNAIRE -- SUMMARY OF RESPONSES FOR ALL EXPERIMENTS (Cont)

### Subject #2

4. What were the best and worst features of ensemble? (specify)

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. best features | -- | -- | -- | -- | -- | -- | -- |
| b. worst features | rectal probe | electrodes on face | mask; gloves | gloves | gloves; suit too small | gloves | mask |

5. What would you change about last night's ensemble? (specify briefly)

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| | rectal probe | rectal probe | temperature | gloves | the suit-tight in crotch | not wear gloves | mask |

6. What bothered you most about the items listed below? If you were not bothered, write in OK.

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. uniform------ | | | | | x | | |
| b. mask--------- | | | x | | | x | x |
| c. environment-- | | | | | | | |
| d. noise-------- | x | | | | | | |
| e. hood--------- | | | | | | | |
| f. gloves------- | | | x | x | x | x | |
| g. instrumentation | | x | | | | | |
| h. other-------- | | | | | | | |

DEBRIEFING QUESTIONNAIRE -- SUMMARY OF RESPONSES FOR ALL EXPERIMENTS (Cont)

Subject #2

7. About how long did it take to fall asleep last night? (estimated minutes)

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| | 15 | 30 | 45 | 60 | 45 | 30 | 180 |

8. Do you recall dreaming last night?

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. yes------- | | | | | | | |
| b. no-------- | x | x | x | x | x | x | x |

9. How many times did you awaken last night? (estimate number of times)

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| | 3 | 5 | 6 | 4 | 5 | 4 | 2 |
| how does your answer compare to normal? | +1 | +3 | +4 | +1 | +1 | +1 | -- |

10. Do you feel alert and ready to do a day's work?

| exp. # | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| a. yes------- | x | x | | x | x | x | |
| b. no-------- | | | x | | | | x |